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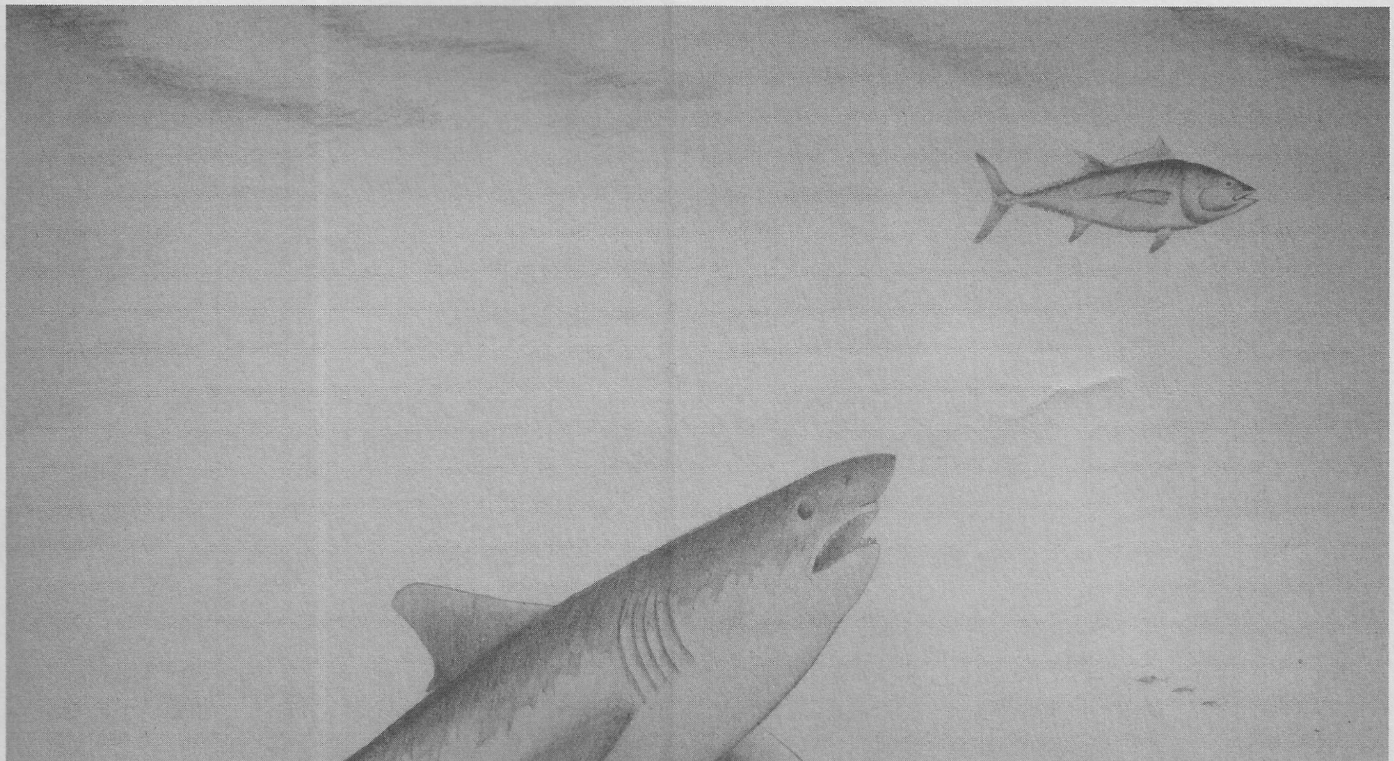

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Upper Cretaceous Macroinvertebrate Faunas of the Northern Atlantic Coastal Plain

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ABSTRACT - A paleontological investigation was conducted on the Late Cretaceous deposits of the northern Atlantic Coastal Plain. Although members of all macroinvertebrate groups are discussed, quantitative work is limited to the bivalves. An appendix documents the temporal and spatial distribution of all known bivalve taxa occurring in this region. Similarity indices, infaunal/epifaunal ratios, and taxonomic diversity have been calculated from this data. Using several lines of evidence, Weller's (1907) *Cucullaea* - *Lucina* faunal model is shown to be an oversimplification.

Geological Overview

The Late Cretaceous deposits of the northern Atlantic Coastal Plain exemplify the dynamic nature of past sedimentary processes. The most important factors affecting large scale depositional regimes in this region are sea level fluctuations and the tectonic nature of the receiving basin (Owens and Gohn, 1985).

Weller (1907) first recognized that cyclic sea level change played a major role in determining the New Jersey sequence. Owens and Sohl (1969) also documented cyclicity in these sediments. In their model (see Figures 1 and 2), each sedimentary cycle begins with the deposition of an outer-shelf, transgressive, glauconitic unit. Then, as sea level regresses, inner-shelf, clay-silt units are deposited. Finally, each cycle concludes with the deposition of a near-shore, sand unit.

Tectonic structure also influenced Late Cretaceous depositional patterns in the northern Atlantic Coastal Plain. There are three major tectonic features: the Raritan Embayment, Salisbury Embayment, and South Jersey High (Olsson, 1975). These features are defined by the relative thicknesses of the overlying stratigraphic sequence, subsurface relief, and sedimentological differences in both the surface and subsurface (Wolfe, 1977).

Evidence that these structural features influenced Late Cretaceous depositional regimes is as follows: 1) the Upper Cretaceous sequence is thicker in the Raritan Embayment than in the Salisbury Embayment, or on the South Jersey High, 2) unlike elsewhere in the study region, fine clastics predominate in the Salisbury Embayment, indicating a deeper water depositional environment, and 3) the outcropping units of the Salisbury Embayment do not extend as deep into the subsurface as do those same units in the Raritan Embayment, or on the South Jersey High (Wolfe, 1977).

New Jersey Cretaceous Sequence

Berriasian Through Santonian Stages

The Potomac Group (Berriasian - Early Cenomanian) represents the oldest Cretaceous strata in the northern Atlantic Coastal Plain. In the Raritan Bay region, these beds are overlain by the Raritan Clay, Farrington Sand, and Woodbridge Clay Members (Late Cenomanian - Early Turonian) of the Raritan formation (Owens and Gohn, 1985).

The Late Cenomanian - Early Turonian was marked by a transgression. The Woodbridge Clay Member, which consists of massive silty clays, and interbedded clays and sands (Owens et al., 1977), was deposited at this time (Petters, 1976). This unit contains the biostratigraphically restricted ammonites *Metoicoceras bergquisti* and *Metengonoceras*, suggesting a Late Cenomanian age (Cobban and Kennedy, 1990).

Beginning in the Late Turonian, a regressive phase occurred. The Sayreville Sand and South Amboy Clay Members (Coniacian?) of the Raritan formation were deposited during this event (Petters, 1976). The Sayreville Sand Member consists of cross-bedded, medium to coarse-grained quartz sand (Owens et al., 1977). The South Amboy Clay Member is similar to the Woodbridge Clay Member, but is thinner and more localized in extent (Owens and Sohl, 1969).

After deposition of the South Amboy Clay Member, a transgressive phase laid down the Magothy formation (Petters, 1976). This unit contains the Late Santonian-Early Campanian index fossils *Ostrea cretacea* and *Baculites asper* (Sohl and Mello, 1970).

Three facies characterize the Magothy in the Raritan Bay region (Owens et al., 1977): 1) a basal, micaceous, massive silt facies (Amboy stoneware clay), 2) a middle facies (Morgan beds), consisting of intercalated sands and silty clays, and 3) an upper facies (Cliffwood beds) consisting predominately of cross-bedded sands.

Campanian Stage

After Magothy deposition, another transgressive event laid down the Merchantville formation. This unit can be divided into three facies along strike (Owens et al., 1977): 1) thin-bedded (2-6 inches thick) intervals of micaceous, clayey silts, and occasional massive glauconite sands, in the Raritan Bay region, 2) thick-bedded (5-15 feet thick) sequences of clayey quartz silts interbedded with quartz-glauconite sands, in the west-central region, and, 3) massive glauconite-quartz sands, in the

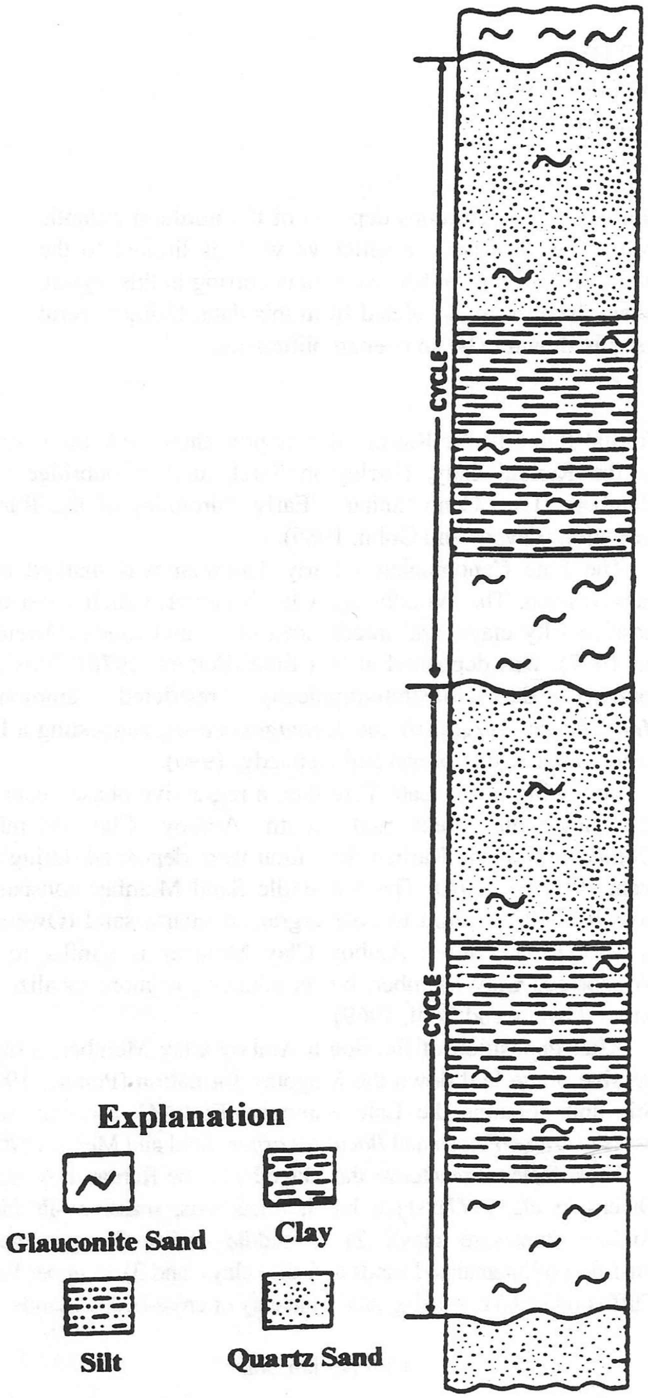

Figure 1. Typical depositional pattern exhibited in the Upper Cretaceous sediments of New Jersey and northern Delaware. Each depositional cycle represents one upward-shallowing sequence, bounded by unconformities. (Adapted from Owens, 1970, p. 424).

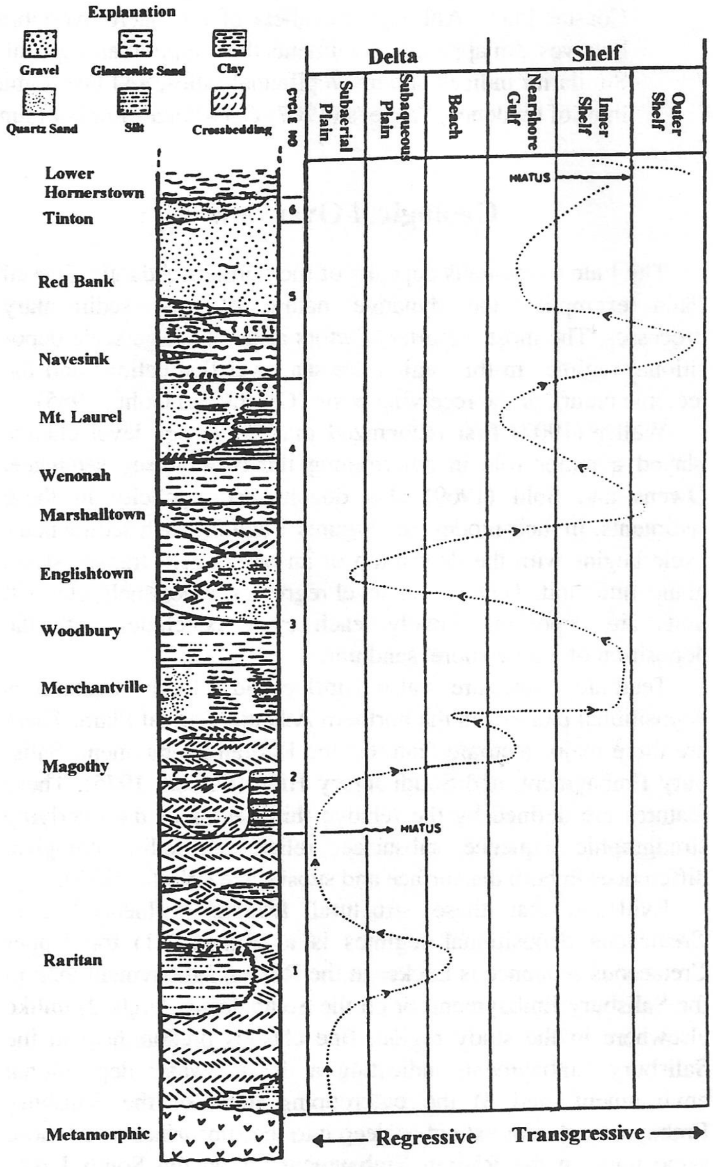

Figure 2. Composite Upper Cretaceous stratigraphic section of New Jersey, indicating depositional cycles. (Adapted from Owens and Sohl, 1969, figure 16).

southwestern region. The Merchantville contains the biostratigraphically restricted ammonite *Scaphites hippocrepis* III, suggesting an Early Campanian age (Kennedy et al., 1995).

The Merchantville is overlain by the clayey, micaceous silts of the Woodbury formation. Formerly, it was thought that the Woodbury pinched out in Gloucester County, New Jersey, and, therefore, was not present in Delaware (e.g. Groot et al., 1954; Richards et al., 1958; Minard, 1965; Owens and Sohl, 1969; Owens et al., 1970). However, the Woodbury is now thought to be present at the C&D Canal (Owens et al., 1977, p. 31, figure 96; see also Carter, 1937, figure 32), and even persist to the eastern shore of the Chesapeake Bay (Minard, 1980, table 2; Owens and Gohn, 1985).

The Woodbury grades upward into the regressive quartz sands and silty clays of the Englishtown formation. This unit is thickest (about 120 feet) in the Raritan Bay region, and thins to about 40 feet in the southwestern region. The Englishtown can be divided into three facies (Owens et al., 1977): 1) thick beds of cross-stratified sands, in the Raritan Bay region, 2) interbedded sands and dark silts, in the west-central region, and, 3) clayey, silty sands, in the southwestern region.

After Englishtown sedimentation, a transgressive phase deposited the Marshalltown formation. Overall, the Marshalltown is a massive, fine-grained sand, locally dominated by silt and clay. The middle and upper parts of the unit contain abundant glauconite, whereas lignitic quartz sands are more characteristic of the basal portion (Owens et al., 1977). The Marshalltown contains the biostratigraphically restricted ammonites *Menuites portlocki complexus* and *Didymoceras binodosum*, suggesting a Middle Campanian age (Kennedy et al., 1995).

The Marshalltown is overlain by the regressive sands of the Wenonah formation. This unit consists predominately of massive to thick bedded, fine, silty, micaceous, quartz sands (Owens et al., 1977). However, Weller (1907, p. 91) mentions that the Wenonah locally "is distinctly laminated, with thin seams of black or chocolate-colored clay." This description was ignored by subsequent authors (e.g. Owens and Sohl, 1969; Owens et al., 1970, 1977), who assign the "thin-bedded intercalated dark clay-light sand sequence" of the Raritan Bay region to the Mt. Laurel formation. The Wenonah contains the biostratigraphically restricted ammonites *Menuites portlocki*, *Trachyscaphites pulcherrimus*, *Didymoceras binodosum*, and *Baculites texanus*, suggesting a Middle or Late Campanian age (Kennedy et al., 1995).

The Wenonah is overlain by another clastic unit: the Mt. Laurel formation. In the west-central and southwestern regions, the Mt. Laurel consists of two facies: 1) massive-bedded, medium-grained quartz sands, capped by, 2) a relatively thin (up to 12 feet thick), glauconitic, pebbly sand bed. In the Raritan Bay region, the unit is thin (up to eight feet thick) and generally consists of a pebbly quartz sand, although at some localities it contains few pebbles and is fairly glauconitic. The Mt. Laurel contains the biostratigraphically restricted ammonites *Didymoceras stevensoni*, *Exiteloceras jenneyi*, *Hoploscaphites vistulensis*, *Jeletzkytes compressus*, and *Didymoceras draconis*, suggesting a Late Campanian age (Kennedy et al., 1995).

Maastrichtian Stage

The quartz sands of the Mt. Laurel are overlain by the clayey, silty, massive glauconitic sands of the Navesink formation. In the Raritan Bay region, the basal Navesink formation contains two distinct ammonite assemblages, one of Late Campanian and the other of Early Maastrichtian age (Kennedy et al., 1995).

In central and northern Monmouth County, the Navesink grades upward into the micaceous, glauconitic clays representing the lower facies (Sandy Hook Member) of the Red Bank formation. The Sandy Hook Member contains the Late Maastrichtian index fossils *Haustator bilira* and *Baculites columna* (Owens et al., 1977). Thus, in part, this unit represents the *Haustator bilira* Zone of Sohl (1977b).

The Sandy Hook Member grades upward into the feldspathic, fine to medium-grained quartz sands representing the Shrewsbury Member of the Red Bank formation. The Shrewsbury Member contains a small percentage of coarse-grained sand and is locally cross-bedded (Owens and Gohn, 1985).

The Shrewsbury Member grades upward into the indurated, glauconitic, quartz sands of the Tinton formation. This unit is unlike the older glauconitic units of the study region (i.e. the Merchantville, Marshalltown, and Navesink formations) in that it is consolidated and contains a high percentage of coarse-grained quartz sand and pebbles (up to 1/4 inch in diameter). The Tinton contains the Late Maastrichtian index fossil *Pterotrigonia cerulia*. This species is restricted to the *Haustator bilira* Zone (Sohl, 1977b, figure 5).

In southern Monmouth County, the Navesink grades upward into dark-gray, clayey, glauconitic sands and clays. Unlike the Sandy Hook Member, this interval contains an abundance of glauconite, but no sand-sized quartz grains (Olsson, 1963). For this reason, Olsson (1960, 1963) concludes that these beds represent a distinct unit: the "New Egypt" formation. However, other workers (e.g. Owens and Sohl, 1969; Owens et al., 1977) simply consider this unit to be a glauconitic facies of the Red Bank formation. Thus, the term "New Egypt" formation should probably be restricted to the subsurface deposits described by Olsson (1960, 1963).

In eastern Monmouth County, the Hornerstown formation overlies the Tinton formation. To the southwest, along strike, the Hornerstown successively overlies the Shrewsbury Member, Sandy Hook Member, and glauconitic facies of the Red Bank formation, and eventually the Navesink formation. Various United States Geological Survey (USGS) studies (e.g. Minard et al., 1969; Owens and Sohl, 1969; Owens et al., 1970) use this as evidence for an angular unconformity separating the Hornerstown from the older sediments. However, based on faunal evidence, several workers (e.g. Koch and Olsson, 1974, 1977) have produced formidable evidence demonstrating that the contact between the Hornerstown and the underlying beds is conformable or paraconformable. The nature of this debate has been thoroughly discussed by Minard et al. (1969).

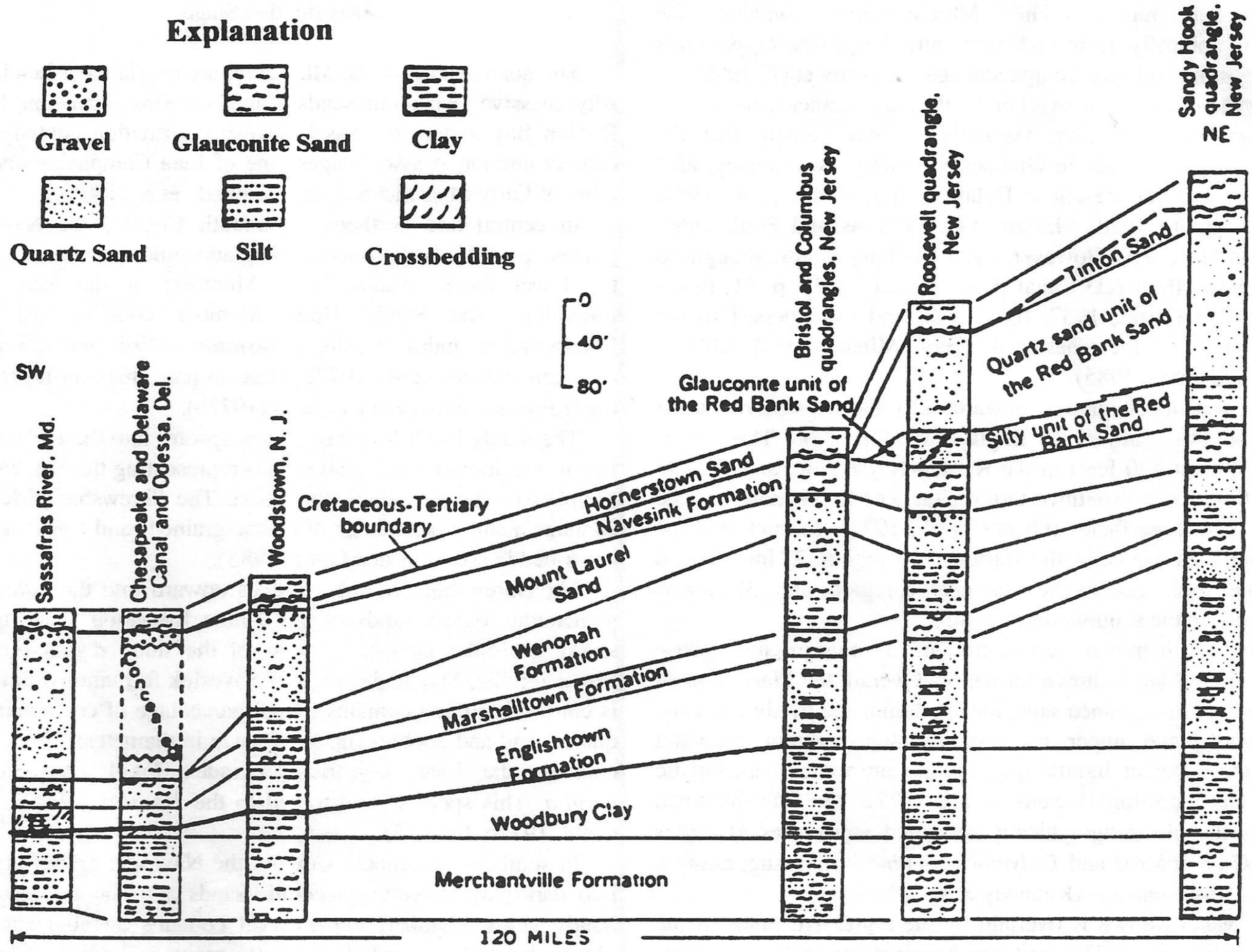
Explanation
Gravel
Glauconite Sand
Clay
Quartz Sand
Silt
Crossbedding
0
40'
80'
SW
Sassafras River, Md.
Chesapeake and Delaware Canal and Odessa, Del.
Woodstown, N. J.
Cretaceous-Tertiary boundary
Hornerstown Sand
Navesink Formation
Mount Laurel Sand
Wenonah Formation
Marshalltown Formation
Englishtown Formation
Woodbury Clay
Merchantville Formation
120 MILES
Glauconite unit of the Red Bank Sand
Bristol and Columbus quadrangles, New Jersey
Roosevelt quadrangle, New Jersey
Tinton Sand
Quartz sand unit of the Red Bank Sand
Silty unit of the Red Bank Sand
Sandy Hook quadrangle, New Jersey
NE

Figure 3. Correlation of the Upper Cretaceous sediments from Atlantic Highlands, New Jersey, to the eastern shore of Maryland. (Adapted from Owens et al., 1970, figure 4).

Delaware and Maryland Cretaceous Sequences

The Upper Cretaceous deposits of the northern Atlantic Coastal Plain progressively thin from about 500 feet in the vicinity of the Raritan Bay to a maximum thickness of 250 feet on the Delmarva Peninsula (see Figure 3). This is due to the thinning of several units along strike, and to the absence of several units present in New Jersey.

The Cretaceous sequence of northern Delaware was formerly well-exposed along the banks of the C&D Canal (Newcastle County, DE). These outcrops exposed the Merchantville, Woodbury, Englishtown, Marshalltown, and Mt. Laurel formations. On the eastern shore of Maryland, exposures consist of streambank outcrops in Cecil and Kent Counties, especially along Little Bohemia, Lloyd, Stillpond, and Sassafras Creeks (Miller, 1926).

Minard et al. (1969) and Owens et al. (1970) claim that the Hornerstown formation overlies the Mt. Laurel on the Delmarva Peninsula. However, this assertion, based on outcrops at Odessa, Bohemia Mills, and Gregg Neck, Maryland, was later retracted. For instance, Minard (1974, p. 22, 23) concedes that in his earlier report (Minard et al., 1969), he mistook the upper strata of these sections for the Hornerstown formation, whereas the beds actually represent the Mt. Laurel, and possibly, include strata equivalent to the Navesink and Red Bank formations. Indeed, lithic and faunal evidence indicates that post-Mt. Laurel Maastrichtian strata thicken on the Delmarva Peninsula (most notably in Kent County, MD), after progressively thinning and pinching out in New Jersey (Minard, 1974; Minard, 1980). Although these beds are stratigraphically equivalent to the Navesink and Red Bank formations of New Jersey, they probably originated from a different source of sedimentation (Minard, 1980). Locally, these deposits contain the Late Maastrichtian index fossils *Haustator bilira*, *Discoscaphites*, and *Sphenodiscus* (Minard, 1974, table 4). Thus, in part, this interval represents the *Haustator bilira* Zone. Due to their lithic homogeneity, Minard et al. (1978) apply the term "Severn" formation to these sediments.

The thickening of strata equivalent to the Navesink and Red Bank formations on the Delmarva Peninsula indicates that an angular unconformity does not mark the Cretaceous-Tertiary (K-

T) boundary in the northern Atlantic Coastal Plain, as suggested by some workers. The Upper Maastrichtian deposits in this region are better explained by a model in which depositional systems changed "in response to shifting centers of maximum deposition and eustatic sea level fluctuations" (Gallagher, 1993). This resulted in section condensation, and several lithofacies, along strike.

The Upper Cretaceous sequence west of the Chesapeake Bay reaches a maximum thickness of 130 feet (Glaser, 1976). Due to its lithic homogeneity, the entire Campanian sequence in this region has been assigned to the "Matawan" formation. Similarly, the entire Maastrichtian sequence has been assigned to the "Severn" formation (Minard et al., 1978). The Severn contains the Late Maastrichtian index fossils *Haustator bilira* and *Discoscaphites conradi*. Thus, in part, this unit represents the *Haustator bilira* Zone.

Faunal Analysis

Raritan Formation

Little was known about the Raritan fauna until Richards (1943) and Stephenson (1954) described many species from the Woodbridge Clay Member. In that unit, macroinvertebrates are contained in sideritic sandstone slabs (Owens and Sohl, 1969), especially in Middlesex County. Specimens have been obtained from clay pits near Sayreville, Woodbridge, East Brunswick, and South River (sites 1, 2, 3 and 4 of Richards et al., 1958).

At the abandoned Sayre and Fisher Company pit in Sayreville (Owens et al., 1977, p. 95), the bivalve *Caestocorbula* and the gastropod *Turritella bakeri* are dominant. Interestingly, many of the *Turritella* specimens are current-oriented. Common subsidiaries include the bivalves *Granocardium*, *Anomia*, *Aphrodina*, *Plicatula*, and the gastropod *Anchura*.

Magothy Formation

New Jersey

Owens and Minard (1964a, 1964b) report a localized occurrence of pyritized fossils in the upper part of the Magothy in the west-central region. However, a more significant Magothy assemblage is contained in small (1-2 inches in diameter) siderite concretions occurring at the base of the "Cliffwood beds" (upper facies of the Magothy), near Cliffwood (Monmouth County, NJ). Collections have been made from clay pits (sites 107, 186 of Weller, 1907), and from a bayside bluff at Cliffwood Beach (site 105 of Weller, 1907; Owens et al., 1977, p. 98).

Sohl (1977a) reports that at Cliffwood Beach, fossils were recovered from two distinct concretion beds. The lower fossiliferous horizon occurs in a dark-gray, clayey silt "from the base of the bluff to below high tide level." In this bed, the bivalves *Pleuriocardia* and *Cymbophora* are dominant. This assemblage is possibly of lower to middle-shoreface origin (Sohl, 1977a).

The upper fossiliferous horizon occurs "Above high tide, in the sands near the base of the bluff." This bed is also dominated by *Pleuriocardia* and *Cymbophora*, however, it contains fewer suspension feeders and more detritus feeders than the lower bed. The upper Cliffwood Beach fauna is indicative of a mixed, lower to upper-shoreface assemblage (Sohl, 1977a).

Weller (1905a) indicates that the bivalve *Veleda lintea* [*Cymbophora trigonalis*] is dominant in the Magothy formation. Common subsidiaries include the bivalves *Pteria*, *Nuculana*, *Glossus*, *Trigonarca*, and *Caestocorbula*, and the small crustacean *Tetracarcinus*.

Delaware

The Magothy formation has yielded a few specimens of *Brachidontes* and a *Teredo*-like bivalve from the C&D Canal in northern Delaware (Sohl, 1977a).

Maryland

Clark (1916, p. 63, 64) reports a meager fauna from Good Hope Hill, Washington, D.C. He indicates that *Panopea*, *Corbula*, and *Turritella* dominate the fauna.

Glaser (personal communication, 9-94) mentions that a few poorly preserved bivalves were obtained from excavations in the Magothy formation at the Bowie (Prince Georges County, MD) municipal landfill (1.6 km southwest of Pigeon House Corner) during the 1970's.

Merchantville Formation

New Jersey

In Monmouth County, Merchantville collections have been made at Cliffwood (site 7 of Richards et al., 1958), Old Bridge Township (site 101 of Weller, 1907), Matawan (site 100 of Weller, 1907), and Union Beach (site 102 of Weller, 1907). In Middlesex County, specimens have been recovered from Jamesburg (sites 139, 140, and 141 of Weller, 1907). In Burlington County, collections have been made at Bordentown (site 31 of Gallagher, 1984), Lenola (site 163 of Weller, 1907), and Maple Shade (site 16 of Richards et al., 1958). In Camden County, Merchantville (site 162 of Weller, 1907) has yielded specimens.

At Maple Shade, exposures at the abandoned Graham Brickyard pit are abundantly fossiliferous (see Appendix II, collection 2). The annelid *Longitubus*, the gastropods *Anchura* and *Arrhoges*, and the bivalves *Granocardium*, *Glycymeris*, *Aphrodina*, and *Camptonectes* are dominant. Common subsidiaries include the bivalves *Pterotrigonia*, *Nucula*, *Nemodon*, *Cucullaea*, *Veniella*, *Inoceramus*, *Neithea*, *Panopea*, *Pholadomya*, *Pinna*, *Cyprimeria*, *Legumen*, *Linearia*, *Striarca*, *Anomia*, and *Paranomia*, the gastropods *Euspira*, *Gyrodes*, *Turritella*, *Pyrifusus*, *Xenophora*, and *Volutomorpha*, and the ammonites *Placenticeras*, *Hoploscaphites*, and *Baculites*.

Delaware

A large Merchantville fauna was collected from former exposures along the C&D Canal (Sohl and Mello, 1970, table 5). Most specimens were recovered from concretions occurring in the lower part of the unit. At this locality, the Merchantville contains a significant number of Aporrhaid and Turritellid gastropods (Sohl, 1977a). Somewhat less common are the bivalves *Nuculana*, *Caestocorbula*, and various pectinids. Interestingly, Carter (1937, p. 255) reports that "Several small crinoid calyces were taken from one of the phosphatic concretions." These were identified as being related to *Hyocrinus* (family Plicatocrinidae).

Woodbury Formation

New Jersey

In Monmouth County, Woodbury collections have been made at Union Beach (site 102 of Weller, 1907), and near Matawan (site 103 of Weller, 1907). In Burlington County, specimens have been recovered from Bordentown (site 21 of Richards et al., 1958) and Crosswicks (site 168 of Weller, 1907). In Camden County, the following localities have yielded specimens: Haddonfield (site 183 of Weller, 1907; sites 12, 13 of Kuehne, 1993), Cherry Hill (site 34 of Gallagher, 1984; sites 2, 11 of Kuehne, 1993), Bellmawr (site 33 of Gallagher, 1984), Haddon (sites 164, 165 of Weller, 1907), Haddon Heights (Kuehne, 1993), and Collingswood (site 25 of Richards et al., 1958). In Gloucester County, Deptford (site 6 of Kuehne, 1993) has yielded specimens.

The Merchantville and Woodbury faunas are remarkably similar, and many of the apparent differences between them can be attributed to differential preservation and collecting bias (Kuehne, 1993). The only major difference lies in the relative abundance of several taxa. For instance, the bivalves *Neithea*, *Glycymeris*, *Panopea*, *Nemodon*, and *Veniella* are far more common in the Merchantville.

At many Woodbury localities in Camden and Gloucester Counties, both aragonitic and calcitic taxa are preserved as original shell material. At Haddonfield, the Woodbury is well-exposed along a tributary of the Cooper River. The small bivalves *Caestocorbula*, *Venericardia*, *Striarca*, *Syncyclonema*, *Lima*, *Tenea*, and *Nuculana* are numerically dominant. Among the larger taxa, *Cyprimeria*, *Aphrodina*, *Gervillia*, *Pinna*, *Camptonectes*, *Pterotrigonia*, and *Granocardium* are dominant. Common subsidiaries include the bivalves *Anomia*, *Nucula*, *Linearia*, *Leptosolen*, *Tellina*, *Legumen*, *Pleuriocardia*, and *Inoceramus*, the gastropods *Pugnellus*, *Gyrodes*, *Euspira*, *Turritella*, *Arrhoges*, *Anchura*, *Volutomorpha*, and *Hercorhyncus*, and the scaphopod *Dentalium*.

Delaware

Sohl (1977a) states that the gastropod *Turritella*, and the bivalves *Pinna* and *Ostrea*, are common in Woodbury exposures along the C&D Canal.

Englishtown Formation

New Jersey

Historically, the Englishtown has been considered to be poorly fossiliferous in New Jersey. However, Richards et al., (1958) and Owens and Minard (1966) report a meager fauna. More recently, Bonfiglio et al., (1987) and Kuehne (1993, site 4) describe a more substantial Englishtown fauna. At their locality, consisting of temporary excavations in Mt. Laurel Township (Burlington County, NJ), a diverse fauna was recovered from a prominent layer of siderite concretions occurring in a gray, clayey quartz sand. Several additional concretion beds occurred below this layer, however, the concretions in the lower beds were generally small (1-2 inches in diameter) and unfossiliferous. Based on the descriptions of Owens and Minard (1962, 1966), this interval represents the basal Englishtown formation. The bivalves *Granocardium* and *Pleuriocardia*, and the gastropod *Haustator* dominate the assemblage. Common subsidiaries include the gastropod *Pugnellus*, and the bivalves *Aphrodina*, *Tellina*, *Cymella bella*, *Leptosolen*, *Tenea*, *Camptonectes*, and *Crassatella*.

A subsequent reexamination of the Englishtown (Kuehne, 1995) revealed that it is fossiliferous at several other widespread localities in New Jersey. Both sites (Auburn and Cherry Hill) described by Kuehne (1995) expose the dark-gray, silty sand facies of the Englishtown discussed by Owens and Sohl (1969). This facies only occurs in the southwestern region.

At Auburn (Salem County, NJ), both calcitic and aragonitic taxa are preserved as original shell material in exposures along a small gully adjoining a tributary of Oldmans Creek. The scaphopod *Dentalium* and the small bivalves *Lucina*, *Striarca*, and *Caestocorbula*, numerically dominate the assemblage. Dominant among the larger taxa are the bivalves *Cyprimeria*, *Tellina*, and *Veniella*, the gastropod *Haustator*, and the inarticulate brachiopod *Lingula*. Common subsidiaries include the bivalves *Granocardium*, *Camptonectes*, *Nucula*, *Nuculana*, *Crassatella*, *Pterotrigonia*, *Aphrodina*, *Nemodon*, and *Cymbophora*.

At Cherry Hill (Camden County, NJ), a diverse, but poorly preserved (clay molds and casts), fauna occurs in exposures along Tindale Run. The bivalves *Granocardium*, *Cymbophora*, and *Striarca*, and the gastropod *Haustator* are dominant. Common subsidiaries include the bivalves *Syncyclonema*, *Veniella*, and *Cymella bella*.

Delaware

Sohl and Mello (1970, table 6) describe an assemblage occurring in a thin sandstone layer at the top of the Englishtown formation along the C&D canal. The bivalves *Pleuriocardia* and *Cymbophora* are dominant (Sohl, 1977a). The occurrence of the gastropod *Pachymelania* suggests brackish water input.

Marshalltown Formation

New Jersey

In Burlington County, Marshalltown collections have been made near Mt. Laurel (site 32 of Richards et al., 1958; Springdale Road Locality of Clements, 1988b). In Salem County, Marshalltown (site 190 of Weller, 1907) has yielded specimens. Collections have also been made at the following Gloucester County localities: Swedesboro (site 177 of Weller, 1907), Auburn (site 180 of Weller, 1907), Woodbury (Credner, 1870), Deptford Township (site 36 of Gallagher, 1984), Mantua (Clements, 1989a), Harrisonville (site 179 of Weller, 1907), and Penns Grove (site 31 of Richards et al., 1958).

The Marshalltown is the oldest formation in the study region containing a well-developed epifauna. Ostreids are abundant, especially *Agerostrea*, *Exogyra*, *Pycnodonte*, and *Gryphaeostrea*. In the west-central region, the fauna is sparse and poorly preserved. However, in the southwestern part of the state, macroinvertebrates are abundant and often well-preserved.

Southwest of Swedesboro, both calcitic and aragonitic taxa are preserved as original shell material in exposures along a small stream emptying into a tributary of Oldmans creek (see Appendix II, collection 4). This is Weller's classic locality. Interestingly, Richards et al. (1958, p. 23) reports that "careful investigation during recent years has failed to rediscover it." However, the site was relocated in 1975 by several members of the Monmouth Amateur Paleontologist's Society (MAPS). The bivalves *Agerostrea*, *Exogyra*, *Anomia*, *Neithea*, *Pycnodonte*, *Gryphaeostrea*, *Granocardium*, *Cucullaea*, *Cyprimeria*, *Nucula*, and *Pterotrigonia* are dominant. Common subsidiaries include the bivalves *Paranomia*, *Lucina*, and *Veniella*, and the gastropod *Turritella*.

Delaware

An extensive Marshalltown fauna, characterized by an abundance of the bivalves *Agerostrea* and *Exogyra*, and somewhat fewer *Pycnodonte*, *Cucullaea*, *Pleuriocardia*, *Pterotrigonia*, *Cyprimeria*, and *Crassatella*, has been recovered from the C&D canal locality (Sohl and Mello, 1970, table 7; Sohl, 1977a). Aragonitic forms are preserved as phosphatic internal molds, but the ostreids retain original shell material (Sohl, 1977a).

Sohl (1977a) reports concentrations of the ostreid *Lopha panda* in the Marshalltown formation of Delaware. He states that the clasping projections of individual specimens wrap "around a cylindrical impressed attachment scar suggesting that they were clinging to stalked vegetation."

Similarly, Sohl and Mello (1970) record "local concentrations of articulated valves of *Lopha* [*Agerostrea*] *falcata* (Morton) that form rounded patches as much as 10 or 12 inches in diameter." The further state that "The specimen orientation suggests that these concentrations may be derived from disintegration of a stalked plant to which the oysters were attached."

Wenonah Formation

Massive Sequence

Wenonah collections have been made near Matawan (site 33 of Richards et al., 1958), Crawfords Corner (site 126 of Weller, 1907), Marlboro (site 130 of Weller, 1907), and Walnford, in Monmouth County.

In the southwestern region, macroinvertebrates are uncommon in the Wenonah formation. Only a few specimens of *Granocardium* and *Agerostrea* were recovered during the present investigation. In the west-central and Raritan Bay regions, a more significant assemblage occurs.

Southeast of Walnford, outcrops along Crosswicks Creek are abundantly fossiliferous (see Appendix II, collection 8). Small bivalves such as *Caestocorbula* and *Nuculana* are numerically dominant. Among the larger taxa, *Cymbophora*, *Agerostrea*, *Granocardium*, and *Chlamys*, are dominant. Common subsidiaries include the bivalves *Syncyclonema*, *Tellina*, *Pterotrigonia*, and *Crassatella*.

Outcrops along Big Brook, near Marlboro, locally contain a well-preserved fauna downstream from the Boundary Road bridge (see Appendix II, collection 7). At this locality, both calcitic and aragonitic taxa are preserved as original shell material. Small bivalves such as *Nuculana* are numerically dominant. Among the larger taxa, *Granocardium*, *Cymbophora*, *Flemingostrea*, *Agerostrea*, *Linearia*, *Tellina*, *Chlamys*, and *Crassatella*, are dominant. Common subsidiaries include the bivalves *Nucula*, *Pterotrigonia*, *Aphrodina*, *Leptosolen*, *Legumen*, *Inoceramus*, and *Lycettia*, the annelid *Hamulus*, the gastropod *Haustator*, and the ammonite *Didymoceras*.

Intercalated Sequence

Weller (1907, p. 91) mentions that the Wenonah is locally "distinctly laminated, with thin seams of black or chocolate-colored clay." Despite this description, Owens et al. (1977) assign the "thin-bedded intercalated dark-clay light-sand" sequence of the Raritan Bay region to the Mt. Laurel formation. Interestingly, however, they state that the clay beds of the intercalated sequence contain "large concentrations of mica" and "sand-sized carbonaceous matter."

These features are far more characteristic of the Wenonah formation. For instance, Owens et al. (1977) mention that the transition from the Wenonah to the Mt. Laurel is marked by a "noticeable decrease in mica" and that, in the Wenonah, "Very fine grained carbonaceous matter is abundant, and locally, small pieces of carbonized wood are common." Furthermore, in his discussion of the Wenonah, Minard (1965) reports that "Mica and carbonaceous matter are particularly diagnostic of this unit." Paleontological evidence also suggests that the intercalated sequence is best assigned to the Wenonah formation. For instance, characteristic Mt. Laurel taxa such as *Exogyra*, *Pycnodonte*, and *Belemnitella* are entirely absent from this interval, but typical Wenonah forms are common.

Southwest of Holmdel, an outcrop along Willow Brook immediately downstream from the mouth of the tributary described by Jengo (1982, p. 141, site 21), exposes about 12 feet of the intercalated sequence. At about 10 feet above stream level, a sand bed (1.5 feet thick) separates two thicker intervals consisting of intercalated layers of clay and sand. This sand bed contains a typical Wenonah assemblage. The bivalve *Granocardium* is dominant. Common subsidiaries include the bivalves *Syncyclonema*, *Tellina*, and *Pterotrigonia*.

An updip exposure near Matawan has also yielded an assemblage from the intercalated sequence (see Jengo, 1982, p. 107-112). Jengo records the echinoids *Hardouinia* sp. and *Hardouinia mortoni emmonsi*, the bivalves *Trachycardium* [*Pleuriocardia*] and *Inoceramus*, and various trace fossils. The ammonite *Placenticeras minor* was subsequently reported from this locality (Kennedy and Cobban, 1994). R. Johnson (personal communication, 9-94) mentions that there were several distinct echinoid-bearing horizons at this site. Interestingly, he states that the echinoids were oriented in life-position, and situated on the sand-clay contacts.

Mount Laurel Formation

New Jersey

In Monmouth County, Mt. Laurel collections have been made at Middletown (site 113 of Weller, 1907), Marlboro (site 130 of Weller, 1907; Owens et al., 1977, p. 102), and near Arneytown (sites 148, 195 of Weller, 1907; site 12 of Jengo, 1982). In Burlington County, specimens have been recovered from Mount Laurel (site 166 of Weller, 1907) and Evesboro Township (Clements 1989b). In Gloucester County, specimens have been obtained from Barnsboro (site 55 of Richards et al., 1958) and Mullica Hill (site 169 of Weller, 1907).

Historically, the Mt. Laurel fauna was not considered distinct from that of the Navesink (e.g. Weller, 1907; Richards et al., 1958, 1962). However, a faunal distinction can be made. For instance, only the Mt. Laurel contains *Exogyra cancellata* and *Anomia tellinoides*, and only the Navesink contains the small brachiopod *Choristothyris plicata* (Carter, 1937; Sohl and Mello, 1970).

In the southwestern and west-central regions, the Mt. Laurel commonly contains localized, low-diversity shellbeds dominated by one or more bivalve taxa such as *Agerostrea*, *Neithea*, *Exogyra*, and *Pycnodonte*, and the cephalopod *Belemnitella*. In the west-central region, a well-defined shellbed dominated by these forms lies about 3 feet below the top of the unit. In the southwestern region, a similar bed lies immediately beneath the Navesink. Other common faunal elements in this bed include the bivalves *Anomia*, *Paranomia*, *Ostrea*, *Agerostrea*, *Gryphaeostrea*, *Plicatula*, *Chlamys*, *Cucullaea*, and *Lima*.

The Mt. Laurel is about 4 feet thick in outcrops along Big Brook, near Marlboro. Due to the admixture of a significant percentage of glauconite with the typical sand constituency at this locality, the sediments of this interval are readily confused with those of the overlying Navesink in unweathered outcrops. However, in the highly weathered outcrops upstream from the Boundary Road bridge, the distinction between the two units is conspicuous.

Although no well-defined shellbeds are discernable, the unit is abundantly fossiliferous throughout. The bivalve *Exogyra*, the cephalopod *Belemnitella*, the ghost shrimp *Protocallianassa* (isolated appendages), and a Cidarid-type echinoid (isolated spines) are dominant. Various bivalve and gastropod steinkerns, such as *Nuculana*, *Nemodon*, and *Pyropsis*, are also common.

The basal 6 inches of the Mt. Laurel is noteworthy in that it often contains sandstone slabs (up to 12 inches in diameter), flat and elongated siderite concretions (up to 6 inches in length), and occasional, large, rounded quartz pebbles (up to 2 inches in diameter). The sandstone slabs are yellowish, pebbly, partially to completely lithified, and abundantly fossiliferous (mainly the bivalves *Gryphaeostrea*, *Agerostrea*, *Granocardium*, *Anomia*, and *Syncyclonema*).

Delaware

The most significant locality where the Mt. Laurel fauna has been studied is the Biggs farm locality along the C&D Canal. Owens et al. (1970, p. 16, 17) assign the Biggs farm exposures to the lower part of the Mt. Laurel formation. Richards and Shapiro (1963) list 132 macroinvertebrate species from this site. Sohl and Mello (1970, p. 45; table 8) revise the faunal list somewhat. Interestingly, much of the aragonitic shell material has been replaced with phosphate, a rare mode of preservation.

Richards and Shapiro (1963) indicate that the solitary coral *Micrabacia*, the bivalves *Anomia tellinoides* and *Agerostrea falcata*, the gastropod *Lunatia* [*Euspira*] *halli*, and the cephalopod *Belemnitella* are the most abundant taxa. Other common forms include the boring sponge *Cliona*, the bivalves *Corimya*, *Clavagella*, *Liopistha*, *Lucina*, *Postligata*, *Glycymeris*, *Yoldia* [*Nuculana*] *gabbana*, *Pecten* [*Chlamys*] *venustus*, *Exogyra cancellata*, *Agerostrea mesenterica*, and *Anomia argentaria*, the gastropods *Margaritella*, *Polinices*, and *Acteon*, and the ammonite *Baculites*.

Navesink Formation

In Monmouth County, Navesink collections have been made at Atlantic Highlands (site 108 of Weller, 1907), Red Bank (site 120 of Weller, 1907), Crawfords Corner (site 126 of Weller, 1907), Middletown (sites 113, 121 of Weller, 1907; Owens et al., 1977, p. 104), Marlboro (sites 127, 128, 130, 131, and 194 of Weller, 1907; Owens et al., 1977, p. 102), Freehold (site 133 of Weller, 1907), and near Arneytown (sites 147, 148, 149, and 195 of Weller, 1907). In Burlington County, specimens have been recovered from Jacobstown (site 150 of Weller, 1907), Birmingham (site 51 of Richards et al., 1958), and Evesboro Township (Clements, 1989b). In Camden County, specimens have been recovered from Runnemede (site 52 of Richards et al., 1958). In Gloucester County, specimens have been obtained from Barnsboro (site 55 of Richards et al., 1958), Sewell (site 56 of Richards et al., 1958), and Mullica Hill (site 169 of Weller, 1907).

At Atlantic Highlands, the basal Navesink locally contains a highly diverse and prolific assemblage in outcrops near the base of a large bluff facing the Raritan Bay (see Appendix II, collection 11). Especially noteworthy is the diverse assemblage of deep-water, heteromorphic ammonites. Two distinct shellbeds can be recognized. The lower bed is 6-8 inches thick, and lies 27 inches above the base of the unit. The upper bed is 5 inches thick, and lies 8 inches above the lower layer (Cobban, 1974). The lower bed is the main fossil-producing horizon (R. Johnson, personal communication, 11-96).

Five shellbeds occur in the lower Navesink along Big Brook, near Marlboro (site 130 of Weller, 1907). The oldest bed lies about 2 feet above the base of the unit. The small bivalve *Chlamys venustus* is dominant in this bed. Common subsidiaries include the bivalves *Exogyra*, *Pycnodonte*, and *Chlamys whitfieldi*, the cephalopod *Belemnitella*, and isolated Cidarid echinoid spines. In addition, this bed locally contains an abundance of isolated columnals belonging to the small crinoid *Dunnicrinus*. Another shellbed occurs about 5 feet above the base. This bed is similar to the basal bed, but contains far fewer specimens of *Belemnitella*. Two poorly defined shellbeds occur about 7 and 8.5 feet above the base. Their faunal composition is similar to the bed at 5 feet.

The most prominent shellbed occurs about 12 feet above the base. This bed is also exposed along Poricy Brook, near Middletown, downstream from Middletown-Lincroft Road (Owens et al., 1977, p. 104). The bivalves *Pycnodonte*, *Agerostrea mesenterica*, and *Chlamys venustus* are dominant. Common subsidiaries include the bivalve *Lima*, the brachiopod *Choristothyris*, the cephalopod *Belemnitella* (diminutive specimens), and the crinoid *Dunnicrinus* (isolated columnals). *Ostrea* [*Lopha*?] *monmouthensis* and *Exogyra costata spinifera* also occur, but are far less common.

In the west-central and southwestern regions of New Jersey, the basal Navesink contains a diverse shellbed (although far less diverse than the one occurring at Atlantic Highlands). At Mullica Hill, the basal 2-3 feet of the Navesink is indurated, and abundantly fossiliferous (see Appendix II, collections 9 and 10). The fauna is dominated by the bivalves *Agerostrea*, *Cucullaea*, *Pycnodonte*, *Plicatula*, *Chlamys*, *Crassatella*, and *Granocardium*. Common subsidiaries include the bivalves *Glycymeris* and *Veniella*, the gastropods *Euspira*, *Arrhoges*, and *Turritella*, and the cephalopod *Belemnitella*.

Red Bank Formation

Glauconitic Facies

East of Arneytown, an outcrop along Crosswicks Creek exposes the uppermost Navesink and the glauconitic facies of the Red Bank formation (see Appendix II, collection 12). Although the contact is gradational, these units contain distinct macroinvertebrates assemblages. The upper Navesink is a glauconitic clay dominated by the bivalves *Chlamys*, *Pycnodonte*, *Exogyra*, and *Agerostrea*. A less fossiliferous interval (about 3 feet thick) overlies the Navesink shellbed. The sediment above this layer is partially indurated, more clayey, and abundantly fossiliferous. This interval represents the glauconitic facies of the Red Bank formation. The fauna is dominated by the bivalves *Cucullaea*, *Pycnodonte, Chlamys*, *Exogyra*, *Granocardium*, and *Veniella*, and the gastropods *Anchura*, *Haustator*, *Pyropsis*, and *Euspira*.

Sandy Hook Member

Sandy Hook collections have been made at Middletown (site 112 of Weller, 1907; Owens et al., 1977, p. 104), Hazlet (site 129 of Weller, 1907), and Red Bank (sites 116, 119 of Weller, 1907), in Monmouth County.

At Middletown, the Sandy Hook Member is well-exposed along Poricy Brook, especially upstream from Middletown-Lincroft Road. The unit consists of micaceous, glauconitic clay, and contains many *Ophiomorpha*-like burrow structures filled with dark-green glauconite. Overall, the unit contains a relatively sparse fauna dominated by *Gryphaeostrea* and *Pycnodonte*. *Exogyra costata* and *E. costata spinifera* are common subsidiaries.

A far more diverse fauna occurs locally, especially higher in the section (see Appendix II, collections 13 and 14). Both aragonitic and calcitic taxa are preserved as original shell material. The small bivalves *Nuculana*, *Crenella*, *Cubitostrea*, *Striarca*, and *Lucina* are numerically dominant. Among the larger taxa, *Agerostrea* and *Cymbophora* are dominant. The gastropod *Haustator* is also common.

Shrewsbury Member

Few fossils are known from the Shrewsbury Member, probably due to few good exposures and diagenic leaching of the shell material. Weller (1907, site 123) describes the only macroinvertebrate collection ever made (Red Bank, Monmouth County, NJ). This assemblage consists of the bivalves *Agerostrea*, *Pycnodonte*, *Gryphaeostrea*, *Chlamys*, and *Lima*.

Tinton Formation

Tinton collections have been made at Tinton Falls (site 110 of Weller, 1907; Owens et al., 1977, p. 106; Sohl and Koch, 1984, p. 166), Hazlet (site 129 of Weller, 1907; Sohl and Koch, 1984, p. 172), and near Colts Neck (site 132) and Jackson Township (sites 123 and 152 of Weller, 1907), in Monmouth County.

At Tinton Falls, exposures along Pine Brook are abundantly fossiliferous, both upstream and downstream from Tinton Avenue (see Appendix II, collection 15). The crustacean *Protocallianassa* (isolated appendages), and the bivalves *Agerostrea*, *Chlamys*, *Syncyclonema*, *Pycnodonte*, and *Gryphaeostrea* are dominant. Common subsidiaries include the bivalves *Granocardium* and *Glycymeris*, the gastropod *Turritella*, and the ammonite *Sphenodiscus*.

At Hazlet, the Tinton is exposed near the top of a roadcut dissecting Crawford Hill. The fauna is dominated by the bivalves *Granocardium* and *Pterotrigonia*. Common subsidiaries include the bivalves *Glycymeris* and *Crassatella*.

Basal Hornerstown Formation

The basal Hornerstown formation contains a noteworthy concentration of Cretaceous fossils which has been informally dubbed the "MFL" (Main Fossiliferous Layer). In the past, the MFL was exposed in numerous "marl" pits, where glauconite was mined as a fertilizer. Today, only the Inversand Company pit in Sewell, Gloucester County (Owens et al., 1977, p. 107), is actively worked. Although this site displays the most extensive MFL outcrop, exposures also occur near Stratford, Camden County (site 51 of Gallagher, 1984), Blackwood Terrace, Gloucester County (site 49 of Gallagher, 1984), and Arneytown, Monmouth County (site 102 of Olsson, 1963; site 15 of Gallagher, 1993).

At Sewell, macroinvertebrates are not homogeneously dispersed throughout the MFL (Gallagher, 1993). About 7.5 to 9 cm above the Navesink-Hornerstown contact, the base of the MFL is marked by a dense shellbed exclusively composed of the bivalve *Pycnodonte dissimilaris*. This thin-shelled form represents the most abundant MFL macroinvertebrate at Sewell (Gallagher, 1993).

P. dissimilaris is somewhat less common in the upper part of the MFL, and *Cucullaea vulgaris*, which is overall the second most abundant MFL faunal constituent, dominates this interval (Gallagher, 1993). Common subsidiaries in the upper MFL include the bivalves *Crassatella* and *Panopea*, the gastropods *Turritella* and *Pyropsis*, and the ammonite *Sphenodiscus*.

Matawan Formation

Historically, few fossils have been reported from the Matawan formation. However, recent field investigations demonstrated that the Matawan is far more fossiliferous than past workers have thought. Ironically, this field work revealed that the best locality for Matawan macroinvertebrates has been a well-known vertebrate locality for more than a decade. At this site, along a tributary of the Patuxent River, near Bowie, the uppermost Matawan and basal Severn formations are exposed (see Appendix II, collection 16). About 2 feet above stream-level, the contact is marked by a thin (6 inches thick), pebbly, sandy, vertebrate-producing bed. At this locality, the Severn contains few macroinvertebrates except the bivalve *Aphrodina*. However, the Matawan is abundantly fossiliferous. The bivalves *Aphrodina* and *Pleuriocardia* are dominant. Common subsidiaries include the bivalves *Granocardium*, *Cyprimeria*, *Aenona*, *Legumen*, and *Liopistha*, and the gastropods *Haustator* and *Pugnellus*.

About one mile north of the Bowie locality, a far less prolific Matawan assemblage occurs along White Marsh Branch, a tributary of the Patuxent River (see Appendix II, collection 17). The bivalves *Syncyclonema*, *Aphrodina*, *Pterotrigonia*, *Legumen*, *Linearia*, and *Nucula* are dominant.

At Jones Township, a high bluff facing Round Bay exposes the Matawan (see Appendix II, collection 20). The bivalve *Pleuriocardia* is dominant. Common subsidiaries include the bivalves *Aphrodina*, *Pterotrigonia*, and *Cucullaea*, and the gastropod *Haustator*.

Southeast of Pigeon House Corner, the Matawan is exposed along a small stream emptying into a tributary of the Patuxent River (see Appendix II, collections 18 and 19). The bivalves *Aphrodina* and *Pleuriocardia*, and the gastropod *Haustator* are dominant.

Severn Formation

On the Eastern Shore of Maryland, Severn collections have been made near Stillpond, Kent County (Minard, 1974, table 4; Sohl and Koch, 1984, p. 165). West of the Chesapeake Bay, specimens have been recovered from Prince Georges County, especially near Glenarden (locality 1 of Brouwers and Hazel, 1978), Landover (locality B of Baird, 1986), Largo (locality C of Baird, 1986), Oxen Hill (site F of Baird, 1986), and Seat Pleasant (Clark, 1916, p. 91). Specimens have also been obtained from bluffs along the Severn and Magothy Rivers in Anne Arundel County (Owens et al., 1977, p. 54).

Two macroinvertebrate assemblages can be distinguished within the Severn formation. One occurs in the upper part of the unit, both on the Eastern Shore of Maryland and west of the Chesapeake Bay. The other is apparently confined to the basal beds in a very localized area west of the Chesapeake Bay. Both assemblages contain *Haustator bilira*, and thus, in part, represent the *Haustator bilira* zone of Sohl (1977b). When correlated with the New Jersey faunas, the upper Severn assemblage suggests a Red Bank or Tinton age, whereas the lower assemblage is more indicative of Navesink equivalency.

The lower Severn fauna can be distinguished by the association of *Haustator bilira*, *Exogyra*, *Pycnodonte*, and *Belemnitella*. This assemblage was recorded from a roadcut near Lanham, Prince Georges County (Owens et al., 1977, p. 54; Minard, 1980, p. 12, 13).

The upper Severn fauna is highly diverse and can readily be distinguished from all others in the northern Atlantic Coastal Plain by the association of *Haustator bilira*, *Discoscaphites*, and *Sphenodiscus*. On the Eastern Shore of Maryland, this assemblage occurs along a small tributary of Lloyd Creek, east of Stillpond (see Appendix II, collection 21). Specimens are preserved as clay molds and casts. The bivalves *Agerostrea*, *Cucullaea*, and *Syncyclonema* are dominant. Common subsidiaries include the bivalves *Crassatella*, *Veniella*, *Cubitostrea*, *Botula*, and *Eufistulena*, the gastropod *Turritella*, and the ammonite *Baculites*.

West of the Chesapeake Bay, both aragonitic and calcitic taxa are usually preserved as original shell material. The best exposure occurs along a tributary of Cattail Branch, south of Glenarden (see Appendix II, collection 22). This is the classic "Brightseat" locality from which Gardner (1916) described numerous species. The solitary coral *Micrabacia*, and the small bivalves *Crenella*, *Caestocorbula*, *Cubitostrea*, and *Nuculana* are numerically dominant. Among the larger taxa, *Agerostrea*, *Syncyclonema*, *Postligata*, *Anomia*, *Aenona*, *Nucula*, *Crassatella*, *Cyprimeria*, and *Pterotrigonia* are dominant. Common subsidiaries include the bivalves *Striarca*, *Lycettia*, *Pleuriocardia*, and *Veniella*, the gastropods *Euspira*, *Ringicula*, and *Haustator*, and the ammonites *Sphenodiscus* and *Baculites*.

Cucullaea and Lucina Assemblages

Weller (1905a; 1905b) conducts the earliest critical paleontological review of the New Jersey Late Cretaceous. Weller (1905a) hypothesizes that a stratigraphically recurrent faunal pattern exists in this strata. Weller (1905b) postulates that the more glauconitic units (i.e. Merchantville, Marshalltown, Navesink, and Tinton formations) contain one type of assemblage and that predominantly clay and sand units (i.e. Magothy, Woodbury, Wenonah, and Red Bank formations) contain a different type. Furthermore, he ascribes these two faunas to "local conditions of environment" (p. 149).

Weller (1907) refers to the fauna occurring in glauconitic units as a "*Cucullaea* assemblage," and that occurring in clay and sand units as a "*Lucina cretacea* assemblage." He speculates that these two recurring assemblages preferred different water depths. Therefore, he proposes (p. 180, 181) that cyclic sea level fluctuations played the chief role in determining the biostratigraphical sequence of the New Jersey Late Cretaceous. He concludes that the sediments containing "*Cucullaea* assemblages" were deposited when sea level was relatively high and those containing "*Lucina cretacea* assemblages" were laid down during times of lower sea level.

To further his hypothesis, Weller (1907) uses the total number of species in common between two assemblages to measure relative similarity. However, this method does not take into consideration the diversity of the faunas being compared. Hence, two faunas may numerically have many species in common, and thus superficially appear to be similar, but, in actuality, may be dissimilar, since the number of species in common only represents a small percentage of the total faunal count.

Using the Sorensen similarity index (which takes this factor into account since the number of species in common between two faunas are divided by the average diversity of the faunas) to measure relative similarity, no statistically significant delineation between Weller's faunal types is apparent. In fact, when the similarity indices for each unit are compared (see Table 1), numerous problems with Weller's model soon become apparent.

Table 1. Sorensen similarity indices for the bivalve faunas of the northern Atlantic Coastal Plain. Multiplying the indices by 100 yields percent similarity. Figures were obtained using the data in Appendix I. The Sorensen index is as follows: $SC_s = c / 0.5(A + B)$, where A is the total number of species in community A, B is the total number of species in community B, and c is the number of species common to both communities.
R - Raritan formation; M - Magothy formation; MV - Merchantville formation; WB - Woodbury formation; ET - Englishtown formation; MT - Marshalltown formation; W - Wenonah formation; ML - Mt. Laurel formation; NS - Navesink formation; RB - Red Bank formation; T - Tinton formation; LH - Lower Hornerstown formation; MA - Matawan formation; S - Severn formation

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA
M	0.046												
MV	0.028	0.321											
WB	0.026	0.303	0.608										
ET	0.038	0.268	0.462	0.415									
MT	0.039	0.189	0.402	0.370	0.404								
W	0.033	0.336	0.477	0.433	0.470	0.477							
ML	0.034	0.182	0.379	0.362	0.372	0.457	0.428						
NS	0.014	0.154	0.413	0.376	0.349	0.462	0.461	0.543					
RB	0.035	0.210	0.329	0.395	0.371	0.344	0.386	0.394	0.369				
T	0.000	0.057	0.186	0.190	0.202	0.316	0.210	0.333	0.295	0.433			
LH	0.000	0.077	0.144	0.134	0.169	0.207	0.184	0.214	0.173	0.126	0.227		
MA	0.022	0.214	0.308	0.318	0.427	0.333	0.202	0.293	0.279	0.378	0.237	0.138	
S	0.022	0.104	0.293	0.350	0.344	0.302	0.298	0.351	0.347	0.500	0.254	0.034	0.380

For instance, the Magothy "*Lucina*" fauna is actually more similar to the Merchantville "*Cucullaea*" fauna than to either the Woodbury or Red Bank "*Lucina*" faunas. The Merchantville "*Cucullaea*" fauna is more similar to the Woodbury and Wenonah "*Lucina*" faunas than to either the Marshalltown or Tinton "*Cucullaea*" faunas. The Woodbury "*Lucina*" fauna is significantly more similar to the Merchantville "*Cucullaea*" fauna than to either the Wenonah or Red Bank "*Lucina*" faunas. The Marshalltown "*Cucullaea*" fauna is more similar to the Woodbury, Wenonah, and Red Bank "*Lucina*" faunas than to the Tinton "*Cucullaea*" fauna. The Marshalltown "*Cucullaea*" fauna is also more similar to the Wenonah "*Lucina*" fauna than to the Merchantville "*Cucullaea*" fauna. The Wenonah "*Lucina*" fauna is most similar to the Merchantville and Marshalltown "*Cucullaea*" faunas. The Red Bank "*Lucina*" fauna is most similar to the Tinton "*Cucullaea*" fauna and more similar to the

Marshalltown "*Cucullaea*" fauna than to the Magothy "*Lucina*" fauna. The Tinton "*Cucullaea*" fauna is more similar to the Red Bank "*Lucina*" fauna than to either the Merchantville or Marshalltown "*Cucullaea*" faunas.

Weller (1907) attempts to further bolster his hypothesis by listing (p. 61, 135) the most characteristic forms contained in his *Cucullaea* and *Lucina cretacea* assemblages. This evidence similarly holds no validity. For instance, he describes *Axinea subaustralis* [*Glycymeris mortoni*] and *Cucullaea antrosa* as the two most characteristic species occurring in *Cucullaea* faunas. However, as Sohl and Mello (1970, p. 45) point out, *G. mortoni* is a "wastebasket" term currently designating several distinct species. Furthermore, as stated by Richards (in Richards et al., 1958, p. 77), the type specimen of *C. antrosa* "is a distorted internal mold from an unknown locality in New Jersey." Hence, these forms are useless as characteristic taxa.

Weller (1907) also lists (p. 76) several less characteristic forms which he believed were confined to either his *Cucullaea* or *Lucina cretacea* assemblages. However, several of the species he describes as being confined to his *Lucina* faunas have since been recovered from a *Cucullaea* faunal suite. For instance, *Axinea* [*Striarca*] *congesta* and *Cardium* [*Granocardium*] *dumosum* (*Lucina* assemblage species, according to Weller) both occur in the Merchantville "*Cucullaea*" fauna (Richards et al., 1958, p. 90, 211). Similarly, several species which Weller lists (p. 61) as being confined to his *Cucullaea* faunas, have since been recovered from a *Lucina* faunal suite. For instance, *Neithea quinquecostata* (*Cucullaea* assemblage species, according to Weller) has since been recovered from the Woodbury "*Lucina*" fauna (Kuehne, 1993, p. 65).

Interestingly, Weller mentions that the Merchantville and Woodbury assemblages share many species in common, even though, in his opinion, the Merchantville contains a *Cucullaea* assemblage and the Woodbury contains a *Lucina* assemblage. He observes (p. 60) that the Merchantville contains a "large number of species... which are more normally members of the *Lucina cretacea* fauna." Hence, it is not surprising that more recent investigations of the Woodbury fauna (Richards et al., 1958, 1962; Kuehne, 1993) find that several Merchantville species which Weller lists (p. 61) as being confined to *Cucullaea* assemblages, also occur in the Woodbury "*Lucina*" fauna: *Cucullaea antrosa*, *C. neglecta*, *Axinea subaustralis* [*Glycymeris mortoni*], *Neithea quinquecostata*, *Cardium* [*Protocardia*] *spillmani*, and *Rostellites nasutus*. In addition, Kuehne (1993) finds that several species considered by Weller to be significantly more characteristic of the Merchantville fauna, are actually common in the Woodbury: *Gervilliopsis* [*Gervillia*] *ensiformis*, *Inoceramus proximus*, *Lima reticulata*, *Pinna laqueata*, and *Lunatia* [*Euspira*] *halli*.

Conclusions

The macroinvertebrate assemblages of the northern Atlantic Coastal Plain defy simplistic faunal models, such as that offered by Weller. When the bivalve constituent of the various faunal assemblages are compared with regard to similarity (see Table 1), each fauna is found to be more or less unique. Furthermore, the Raritan bivalve assemblage is far different from the rest, and that of the Magothy is also unusually disparate, but far less so. The relatively great age difference between the Raritan and the Magothy, and between those and the other units, is the most

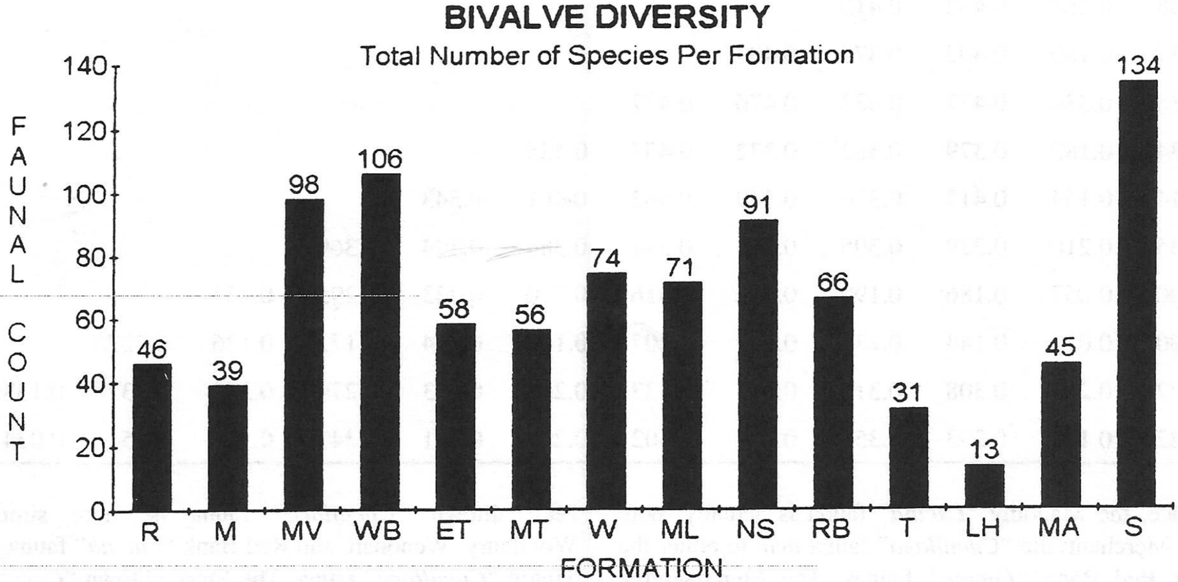

Figure 4. Number of positively identified bivalve species occurring in each Upper Cretaceous unit of the northern Atlantic Coastal Plain.
R - Raritan formation; M - Magothy formation; MV - Merchantville formation; WB - Woodbury formation; ET - Englishtown formation; MT - Marshalltown formation; W - Wenonah formation; ML - Mt. Laurel formation; NS - Navesink formation; RB - Red Bank formation; T - Tinton formation; LH - Lower Hornerstown formation; MA - Matawan formation; S - Severn formation

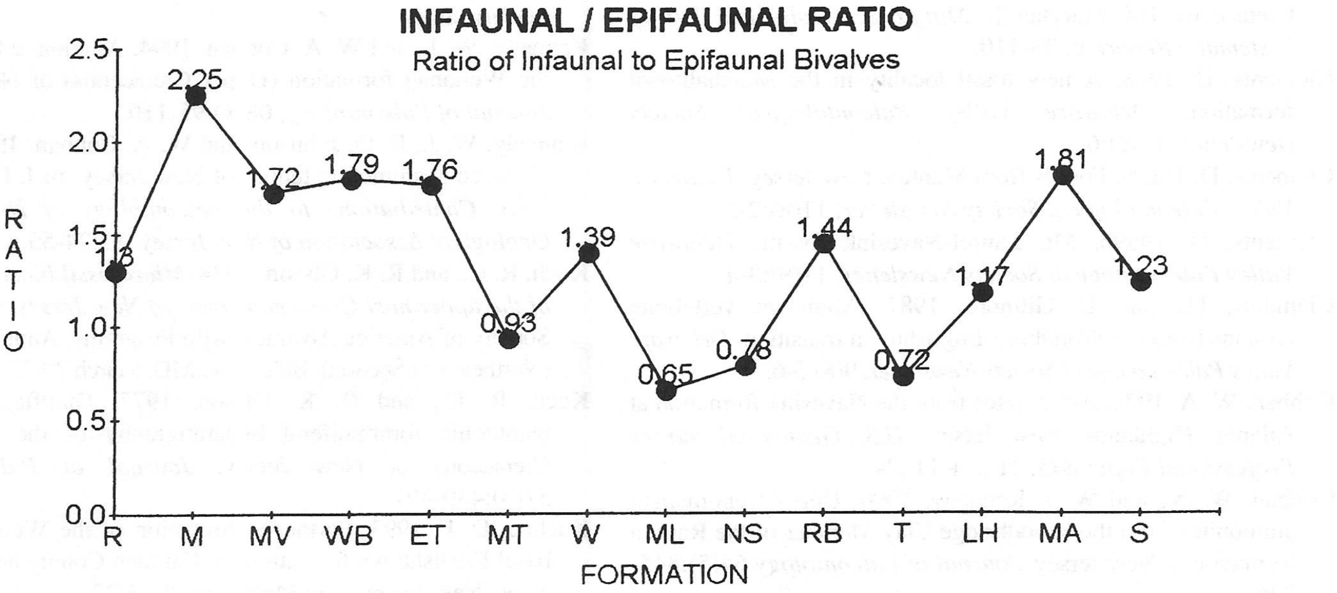

Figure 5. Infaunal/epifaunal ratios for the bivalve assemblages occurring in each Upper Cretaceous unit of the northern Atlantic Coastal Plain.
R - Raritan formation; M - Magothy formation; MV - Merchantville formation; WB - Woodbury formation; ET - Englishtown formation; MT - Marshalltown formation; W - Wenonah formation; ML - Mt. Laurel formation; NS - Navesink formation; RB - Red Bank formation; T - Tinton formation; LH - Lower Hornerstown formation; MA - Matawan formation; S - Severn formation

plausible explanation for this. Among the other units, faunal differences are generally far less pronounced and probably represent a combination of factors, mainly environmental.

When the various bivalve assemblages are compared with regard to diversity (see Figure 4), one important trend is discernable: a decline between the Navesink and Lower Hornerstown formations. The fact that this trend is due mainly to environmental factors, rather than being age-related, is demonstrated by the unusually high diversity of the Severn formation, a unit which is age-equivalent to the Red Bank and Tinton formations. Also noteworthy is the high diversity of the Merchantville and Woodbury assemblages. This feature is superficially made more prominent by the fact that the sub- and superadjacent units contain relatively few taxa.

When the ratio of infaunal to epifaunal taxa contained in each bivalve assemblage are compared (see Figure 5), one important trend is discernable: a gradual decline over time. Although the infaunal/epifaunal ratio is generally thought to be higher in fine-grained sediments and lower in courser ones (Boucot, 1981), such a correlation is not apparent in this study.

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Appendix I

Upper Cretaceous Bivalve Distribution

The following faunal list documents the temporal and spatial distribution of all known Upper Cretaceous bivalve taxa occurring in the northern Atlantic Coastal Plain. Only positive occurrences and identifications are included. This information is primarily based on data presented by Clark et al. (1916), Richards et al. (1958, 1962), Richards and Shapiro (1963), Sohl and Mello (1970), Sohl and Koch (1984), and Kuehne (1993, 1995, unpublished data). Secondary sources include Anderson et al. (1948), Jengo (1982), Johnson and Lescinsky (1985), Gallagher et al. (1986), Bernstein (1988), and Johnson (1986, 1990). Nomenclature follows Moore (1969, 1971), with the exception that *Pleuriocardia* is used instead of *Trachycardium* (see Scott, 1978).

Temporal Distribution:

R - Raritan formation
M - Magothy formation
MV - Merchantville formation
WB - Woodbury formation
ET - Englishtown formation
MT - Marshalltown formation
W - Wenonah formation
ML - Mount Laurel formation
NS - Navesink formation
RB - Red Bank formation
T - Tinton formation
LH - Lower Hornerstown formation
MA - Matawan formation
S - Severn formation

Spatial Distribution:

N - New Jersey
NS - New Jersey (subsurface only)
D - Delaware
M - Maryland
MS - Maryland (subsurface only)
ND - New Jersey and Delaware
DM - Delaware and Maryland
NM - New Jersey and Maryland
A - Reported from all regions

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Class Bivalvia **Subclass Palaeotaxodonta** **Order Nuculoida** **Superfamily Nuculacea** **Family Nuculid**														
Nucula amica Gardner										N			M	M
N. cunifrons Conrad										N				M
N. microstriata Gardner														M
N. percrassa Conrad		N	N	N	N	ND	N			N			M	M
N. slackiana (Gabb)			D	N	N								M	M
N. whitfieldi Weller		N	N	N			N			N				
Superfamily Nuculanacea **Family Malletiidae**														
Malletia longifrons (Conrad)				N	N			D						M
Family Nuculanidae														
Nuculana n. sp.														M
N. cliffwoodensis (Weller)		N												
N. compressifrons Whitfield		N	ND	N										

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
N. gabbana (Whitfield)									N				M	
N. littlii (Gardner)					N					N				M
N. marlboroensis (Weller)							N							
N. pinnaformis (Gabb)				N										
N. pittensis (Stephenson)								D						
N. protexta (Conrad)										N				M
N. protexta (Gabb)									N					
N. rostratruncata (Gardner)													M	M
N. stephensoni Richards			N	N	N		N	D	N	N	N	N		
N. tintonensis (Weller)											N			
N. whitfieldi (Gardner)				N	N					N			M	M
Yoldia cliffwoodensis Weller		N												
Y. papyria (Conrad)				N										
Subclass Pteriomorphia **Order Arcoida** **Superfamily Arcacea** **Family Arcidae** **Subfamily Arcinae**														
Arca obesa (Whitfield)			N											
A. rostellata Morton									N				M	
A. uniopsis Conrad			N						N					
Barbatia assawomanensis Vokes	MS													
B. carolinensis (Stephenson)			D											
B.? cuniculana Stephenson	N													
B. saffordi (Gabb)								M						M
Subfamily Anadarinae														
Anadara cretacea (Conrad)			N	N			N							
Family Parallelodontidae **Subfamily Grammatodontinae**														
Nemodon angulatum (Gabb)					N	N			N					
N. brevifrons Conrad		N			N		N							
N. cecilius Gardner														M
N. conradi Johnson				N										
N. eufaulensis (Gabb)			N	N	N	N		D	N	N	N		M	M

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
N. grandis sohli Richards & Shapiro								D						
N. obesus Stephenson	N													
N. stantoni Gardner										N			M	M
N. uandi (Gardner)														M
Family Cucullaeidae														
Cucullaea n. sp.														M
C. antrosa Morton			N	N				NM	N		N			
C. capax Conrad											N			M
C. carolinensis (Gabb)								M					M	M
C. deatsvillensis (Stephenson)														M
C. harrisvillensis (Richards)	NS													
C. littlei Gabb										N	N			
C. neglecta Gabb			N	N		N	N		N	N				
C. tippana Conrad			D			ND		M	N	N	N		M	M
C. vulgaris Morton												N		
C. woodburyensis Weller				N										
Family Noetiidae **Subfamily Striarcinae**														
Striarca n. sp.	MS													
S. congesta (Conrad)		N	N	N			N			N				
S. cuneata (Gabb)			N	N										M
S. haddonfieldensis (Stephenson)			D	N	N									
S. ruhlei (Richards)	NS													
S. saffordi (Gardner)										N				M
S. umbonata (Conrad)				N	N									
Family Glycymerididae **Subfamily Glycymeridinae**														
Glycymeris compressa (Weller)										N				
G. microdentus (Weller)							N							
G. mortoni (Conrad)			N	N				NM	N		N	N		
G. rotundata (Gabb)											N			M
Subfamily Arcullaeinae														
Postligata crenata Wade								D						

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
P. wordeni Gardner								D		N				M
Trigonarca cliffwoodensis Weller		N												
T. cuneiformis Conrad				N										
T. triquetra Conrad		N												
Order Mytiloida **Superfamily Mytilacea** **Family Mytilidae** **Subfamily Mytilinae**														
Mytilus oblivius Whitfield		N					N		N					
M.? planus Richards	N													
M. smocki Weller									N					
Brachidontes stephensoni Vokes	MS													
Lycettia tippana (Conrad)					N								M	M
L. pectrosa (Conrad)														M
Subfamily Crenaae														
Crenella elegantula Meek & Hayden										N	N			M
C. growi Richards	NS													
C. serica Conrad						ND				N			M	M
Subfamily Lithophaginae														
Lithophaga affinis Gabb			N											
L. julia (Lea)			N	N	D									M
L. twitchelli Gardner														M
Inoperna carolinensis (Conrad)				N	N		N	N	N					M
Subfamily Modiolinae														
Modiolus burlingtonensis (Whitfield)				N										
M. monmouthensis (Weller)			N			N	N						M	
M. sedesclaris Gardner										N				M
M. stephensoni (Vokes)	MS													
M. trigonus Gardner														M
M. wenonah (Weller)							N							
Botula conchafodentis (Gardner)														M
B. lingua (Gardner)														M
B. ripleyana (Gabb)			N				N	M	N			N		M
Superfamily Pinnacea														

	R	**M**	**MV**	**WB**	**ET**	**MT**	**W**	**ML**	**NS**	**RB**	**T**	**LH**	**MA**	**S**
Family Pinnidae														
Pinna laqueata Conrad			ND	N	N				N					M
Order Pterioida **Suborder Pteriina** **Superfamily Pteriacea** **Family Pteriidae**														
Pteria navicula Whitfield				N						N				
P. petrosa (Conrad)		N	ND	N	N		N	M						
P. rhombica Gardner										N				M
Tenuipteria argenteus (Conrad)														M
Family Bakevelliidae														
Gervillia ensiformis (Conrad)			ND	N	N	N	N	N	N	N		N		
G. minima Whitfield									N					
Phelopteria linguiformis (Evans & Shumard)														M
Family Inoceramidae														
Inoceramus confertim-annulatus Roemer									N					M
I. pro-obliqua Whitfield									N					
I. proximus Tuomey	N	N	N	N	N	N	D	D						
I. quadrans Whitfield			N											
Superfamily Pectinacea **Family Oxytomidae**														
Meleagrinella abrupta (Conrad)									N					
Family Entoliidae														
Syncyclonema burlingtonensis (Gabb)			N	N	D		N							
S.? cliffwoodensis (Weller)		N											M	
S. conradi (Whitfield)			ND	N	D				N				M	
S. simplicium (Conrad)			D	N	N			ND		N	N		M	M
Family Pectinidae **Camptonectes Group**														
Camptonectes argillensis (Conrad)														M
C. bellisculptus (Conrad)			ND	N	ND	ND	N		N					
C. bubonis (Stephenson)										N				M
C. parvus (Whitfield)									N					
Chlamys Group														
Chlamys n. sp.						D			N					

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Chlamys craticulus (Morton)								N	N					
C. cretosus (deFrance)														M
C. mississippiensis (Conrad)								ND	N					
C. tenuitestus (Gabb)									N					
C. quinquenarius (Conrad)							N		N					
C. venustus (Morton)						N		D	N	N	N			MS
C. weeksi (Stephenson)								N						
C. whitfieldi (Weller)							N	N	N					M
Neithea Group														
Neithea quinquecostata (Sowerby)		M	ND	N		ND	N	ND	N					M
Family Plicatulidae														
Plicatula n. sp.			D											
P. ferrata Stephenson	N													
P. howelli Richards	N													
P. mullicaensis Weller								D	N					
P. urticosa Morton			N					N	N					
P. woodburyensis Weller				N										
Family Spondylidae														
Spondylus gregalis (Morton)								N	N					
S. echinata (Morton)						N		N	N		N			
Family Uncertain														
Liroscapha squamosa Conrad				N										
Superfamily Anomiacea **Family Anomiidae**														
Anomia argentaria Morton	N	N	ND	N	ND	ND	N	ND	N	N			M	M
A. forteplicata Gardner														M
A. ornata Gabb														M
A. perlineata Wade								N						
A. radiata Weller			ND	N										
A. tellinoides Morton				N				ND	N					
A. urbismarina Vokes	MS													
Paranomia scabra (Morton)			ND			ND	N	ND	N					MS
Superfamily Limacea														

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Family Limidae														
Lima acutilineata Conrad								N						M
L. lorillardensis Weller				N		D								
L. monmouthensis (Whitfield)			N				N							
L. obliqua Gardner														M
L. pelagica (Morton)					N				N					M
L. reticulata Lyell & Forbes			N	N	ND	N	N	ND	N	N	N			M
L. serrata Gardner														M
L. whitfieldi Weller						N	N	N	N					
Plagiostoma errecta (Whitfield)						N	N		N					
Suborder Ostreina **Superfamily Ostreacea** **Family Gryphaeidae** **Subfamily Pycnodonteinae**														
Pycnodonte aucella (Roemer)	NS													
P. convexa (Say)						ND	N	ND	N	N	N			M
P. convexa pusilla (Gardner)								M						
P. dissimilaris (Weller)												N		
Subfamily Exogyrinae **Tribe Exogyrini**														
Exogyra n. sp.									N					
E. cancellata Stephenson								A	N					
E. costata Say				N				NM	N	N	N		M	M
E. c. spinifera (Stephenson)				N		N			N					M
E. ponderosa Roemer			D	N		ND	N							M
E. p. erraticostata (Stephenson)				N		ND								
E. woolmani Richards	NS													
Tribe Gryphaeostreini														
Gryphaeostrea vomer (Morton)					N	ND	N	A	N	N	N	N	M	M
Family Ostreidae **Subfamily Ostreinae** **Nonincubatory Taxa**														
Pseudoperna congesta (Conrad)		N												
Incubatory Taxa														
Ostrea biggsi Richards & Shapiro								D						

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
O. cretacea Morton		N												
O. faba Gardner														M
O. jerseiana Stephenson	N													
O. plumosa Morton				N		N	N	ND	N	N	N			M
O. raritanensis Richards	NS													
O. soleniscus Meek	N													
Cubitostrea tecticosta (Gabb)					D	N	N	NM	N	N				M
Tribe Flemingostreini														
Flemingostrea subspatulata (Forbes)							N							M
Subfamily Lophinae														
Lopha? *monmouthensis* (Weller)									N					M
L. panda (Morton)						N		D						
Agerostrea falcata (Morton)			D			ND	N	ND	N					M
A. mesenterica (Morton)			ND	N		D		ND	N	N	N		M	M
A. nasuta (Morton)									N	N	N		M	M
Subclass Palaeoheterodonta **Order Trigonioida** **Superfamily Trigoniacea** **Family Trigoniidae**														
Pterotrigonia angulicostata (Gabb)										N	N			
P. cerulia (Whitfield)											N			M
P. eufaulensis (Gabb)			N	N	N	N	N	ND	N	N			M	M
P. eufaulensis moorei (Stephenson)														M
P. kummeli (Weller)									N	N				
P. marionensis (Stephenson)													M	
P. thoracica (Morton)			N	N	D	ND	N		N					
Subclass Heterodonta **Order Veneroida** **Superfamily Lucinacea** **Family Lucinidae** **Subfamily Lucininae**														
Lucina glebula Conrad				N						N				
L.? *linearea* (Stephenson)										N				M
L. parva Stephenson				N	N	D		D						
L. parvetineata Schumard										N				

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
L. swedesboroensis Weller						N								
Subfamily Myrteinae														
Myrtea stephensoni Gardner														M
Family Mactromyidae														
Unicardium umbonata (Whitfield)			D			ND			N					
Subfamily Carditamerinae														
Vetericardiella crenilirata (Conrad)			N	N				N		N				M
V. subcircula (Wade)								N						
Superfamily Crassatellacea **Family Astartidae** **Subfamily Astartinae**														
Astarte? *annosa* Conrad	N													
A.? *culebrensis* (Stephenson)														M
A. veta Conrad	N													
Subfamily Eriphylinae														
Eriphyla decemnaria (Conrad)				N										
E. declivis (Conrad)				N										
E. parilis (Conrad)									N					
Subfamily Opinae														
Opis elevata biangulata Stephenson	N													
Family Crassatellidae **Subfamily Crassataae**														
Crassatella sp. B (Stephenson)								D						
C. carolinensis (Conrad)		D	D											
C. cuneata (Gabb)			N				N							
C. hodgei (Stephenson)				N	N									
C. lintea (Conrad)			N	N		N								M
C. prora (Conrad)			N	N										
C. subplana (Conrad)						N	N						M	
C. transversa (Gabb)							N							
C. vadosa (Morton)					N	ND	N	N	N		N	N		M
Bathytormus pteropsis (Conrad)													M	M
Uddenia conradi (Whitfield)			N	N										
U. texana Stephenson										N				M

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Subfamily Scambulinae														
Scambula perplana Conrad				N	D		N							M
S. widmeri Richards				NS										
Superfamily Cardiacea **Family Cardiidae** **Subfamily Cardiinae**														
Granocardium n. sp.			D											
G. cliffwoodensis (Weller)		N												
G. dumosum (Conrad)			ND	N	N	D	N	D		N				M
G. kummeli (Weller)										N	N			M
G. lowei (Stephenson)														M
G. raritanensis (Richards)	N													
G. sayri (Richards)	N													
G. tenuistriatum (Whitfield)		N	ND	N	N	N	N	N	N			N	M	M
G. trilineatum (Weller)									N					
G. uniformis (Weller)			D	N										
G. welleri (Stephenson)					N									
Pleuriocardia eufaulensis (Conrad)		M	D	N	N			DM	N	N			M	M
P. longstreeti (Weller)			D		N		N							
P. lorillardensis (Weller)				N										
P. pilsbryi (Weller)			N											
P. ripleyanum (Conrad)		N	N	N										
P. wenonah (Weller)							N			N				
P. whitfieldi (Weller)				N										
Subfamily Protocardiinae														
Protocardia jerseyensis (Weller)			N											
P. parahillana Wade						D		D						
P. spillmani (Conrad)			ND	N				NM	N				M	M
Nemocardium marinum Vokes	MS													
Subfamily Laevicardiinae														
Laevicardium tenuis (Whitfield)									N					
Superfamily Mactracea **Family Mactridae** **Subfamily Mactrinae**														

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Mactra? n. sp.														M
M.? *pentangularis* Weller				N										
Cymbophora appressa (Gabb)		N					N							M
C. berryi (Gardner)										N				M
C. lintea (Conrad)		N	N	N	N	N	N			N	N			
C. subtilis Stephenson								D						
C. tellinoides (Whitfield)							N							
C. trigonalis Stephenson		N	N											
C. wordeni (Gardner)										N				M
Superfamily Solenacea **Family Cultellidae**														
Leptosolen? n. sp.														M
L. biplicata Conrad		N	N	N	ND		N		N	N			M	M
L.? *elongata* Weller	N									N				M
L.? *terminalis* Weller			N											
Superfamily Tellinacea **Family Tellinidae** **Subfamily Tellininae**														
Tellina n. sp.														M
T. georgiana Gabb					N		N	D					M	
Aenona eufaulensis (Conrad)				N	N					N			M	M
A. papyria Conrad				N										
Linearia n. sp.								D						
L. carolinensis Conrad														M
L. contracta Whitfield			D						N					
L. crebelli Stephenson														M
L. linuifera Stephenson	N													
L. magnoliense Stephenson			D											
L. metastriata Conrad		N	ND	N	ND	ND	N	ND	N	N			M	M
L. ornatissima Weller				N										
L. transcontinentalis Richards	NS													
Solyma elliptica (Gabb)									N					
S. gardnerae Stephenson														M

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
S. lineolatus Conrad		NM	N	N	N		N	N	N	N				
Tellinimera buboana Stephenson										N				M
T. eborea (Conrad)			N	N			N			N				M
T. gabbi (Gardner)				N	N		N		N	N				M
Family Icanotiidae														
Icanotia pulchra Wade								N						
Superfamily Arcticacea **Family Arcticidae**														
Etea carolinensis Conrad			D	N	ND	N							M	M
E. carolinensis aspera (Stephenson)				N										
E. delawarensis (Gabb)				N								N		
Tenea parilis (Conrad)		NM	N	N	N		N	N	N	N	N		M	M
T. pinguis (Conrad)				N	N				N					M
Veniella conradi Morton			ND	N	N	ND	N	A	N	N	N	N	M	M
V. trapezoidea Conrad			N	N			N		N					
Family Neomiodontidae														
Eomiodon maretesta Vokes	MS													
Family Pollicidae														
Neritra polliciformis Stephenson	N													
Superfamily Glossacea **Family Glossidae**														
Glossus bulbosa (Stephenson)								D						
G. cliffwoodensis (Weller)		N		N			N							
G. tintonensis (Weller)											N			
Family Dicerocardiidae														
Ambocardia cooki Whitfield	N													
Superfamily Corbiculacea **Family Corbiculidae**														
Corbicula? *emacerata* Whitfield	N													
C.? *whitfieldi* Richards	N													
Pharodina? *tenuidens* (Whitfield)	N													
Superfamily Veneracea **Family Veneridae** **Subfamily Pitarinae**														

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Aphrodina cretacea (Conrad)				N		N								
A. eufaulensis (Conrad)						N	N	D	N					
A.? johnsoni (Richards)	N													
A. tippana (Conrad)						D							M	M
A. tippana jerseyensis Richards			N	N	N	D								
Subfamily Dosininae														
Dosinia obliquata Conrad														M
Subfamily Cyclininae														
Cyprimeria alta Conrad														M
C. densata (Conrad)			N	N					N					
C. depressa (Conrad)				N	N								M	M
C. excavata (Morton)						ND	N		N					
C. major Gardner														M
C. welleri Stephenson		N		N			N							
Subfamily Tapetinae														
Cyclorisma jerseyensis Richards	NS													
C. parva (Gardner)													M	M
Legumen n. sp.			D											
L. carolinense (Conrad)													M	
L. concentricum Stephenson			D											
L. ellipticum Conrad			D	N				N	N	N			M	M
Order Myoida **Suborder Myina** **Superfamily Myacea** **Family Corbulidae** **Subfamily Corbulinae**														
Corbula atlanticus (Vokes)	MS													
C. monmouthensis Gardner										N				M
C. oceanus (Vokes)	MS													
C. subradiata Gardner														M
C. tethys Stephenson	MS													
Caryocorbula johnsoni Richards	NS													
Subfamily Caestocorbulinae														
Caestocorbula bisulcata (Conrad)		N	N	N	ND								M	

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
C. cliffwoodensis (Weller)		N												
C. crassiplica (Gabb)			ND	N	N	D	N	ND	N	N				M
C. foulkei (Lea)			N	N	N								M	M
C. greywaczi (Richards)	N													
C. jerseyensis (Weller)		N												
C. lorillardensis (Weller)				N										
C. manleyi (Weller)	N													
C. manleyi duplex (Richards)	N													
C. ovisana (Stephenson)	N													
C. percompressa (Gardner)										N				M
C. swedesboroensis (Weller)		N	ND	N		N								
C. terramaria (Gardner)														M
Superfamily Gastrochaenacea **Family Gastrochaenidae**														
Gastrochaena linguiformis Weller			N											
G. whitfieldi Weller									N					M
Superfamily Hiatellacea **Family Hiatellidae**														
Panopea bonaspes Gardner		M												
P. decisa Conrad		N	ND	N		ND	N	N	N	N		N		
P. monmouthensis Gardner														M
Suborder Pholadina **Superfamily Pholadacea** **Family Pholadidae** **Subfamily Pholidinae**														
Clavipholas cithara (Morton)			D											
C. lorillardensis (Richards)				N										
C. pectrosa (Conrad)											N			M
Subfamily Martesiinae														
Martesia cretacea (Gabb)			N		N	ND								
M. cretacea magnatuba Richards	N													
Subfamily Xylophagainae														
Xylophagella irregularis (Gabb)			N	N								N	M	M
X. kummeli Weller			N			N								

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
Family Teredinidae **Subfamily Teredininae**														
Teredo rhombica Gardner														M
Order Hippuritoida **Superfamily Hippuritacea** **Family Diceratidae** **Subfamily Diceratinae**														
Diceras dactyloides Whitfield									N					
Family Requieniidae														
Toucasia jerseyensis (Weller)									N					
Subclass Anomalodesmata **Order Pholadomyoida** **Superfamily Pholadomyacea** **Family Pholadomyidae**														
Pholadomya conradi Gardner														M
P. occidentalis Morton		N	ND	N										
P. roemeri Whitfield					N		N							
Superfamily Pandoracea **Family Laternulidae**														
Laternula cliffwoodensis (Weller)		N												
L. jamesburgensis (Weller)			N											
L. jerseyana (Weller)			N	N			N		N					
L.? robusta Stephenson														M
Anatimya anteradiata Conrad				N			N							M
A. lata (Whitfield)							N							M
Cercomya peculiaris (Conrad)				N										
Periplomya elliptica (Gabb)									N					M
Family Thraciidae														
Thracia tenuis (Whitfield)						N			N					
Superfamily Poromyacea **Family Poromyidae**														
Cymella bella Conrad			D		D									
C. bella texana Stephenson			N	N	N		N							
C. ironensis (Stephenson)			D				N							
C. undata (Meek & Hayden)							N							
Liopistha alternata Weller			N											

	R	M	MV	WB	ET	MT	W	ML	NS	RB	T	LH	MA	S
L. kummeli Weller			N											
L. protexta (Conrad)			ND	N			N	A	N	N	N			M
Family Cuspidariidae														
Cuspidaria ampulla Gardner														M
C. cucurbita Gardner													M	
C. jerseyensis Weller									N					
C. ventricosa (Meek & Hayden)							N			N	N			
Superfamily Clavagellacea **Family Clavagellidae**														
Clavagella armata Morton			N				N	ND	N					
Parastirpulina sohli Pojeta & Johnson									N					

Appendix II

Recent Macroinvertebrate Collections

1: Merchantville fm, Old Bridge Township (Middlesex County, NJ)
2: Merchantville fm, Maple Shade (Burlington County, NJ)
3: Woodbury fm, Deptford (Camden County, NJ)
4: Marshalltown fm, Swedesboro (Gloucester County, NJ)
5: Marshalltown fm, Deptford Twp. (Gloucester County, NJ)
6: Marshalltown fm, Mantua (Gloucester County, NJ)
7: Wenonah fm, Marlboro (Monmouth County, NJ)
8: Wenonah fm, Walnford (Monmouth County, NJ)
9: Mt. Laurel/Navesink fms, Mullica Hill (Gloucester County, NJ)
10: Navesink fm, Mullica Hill (Gloucester County, NJ)
11: Navesink fm, Atlantic Highlands (Monmouth County, NJ)
12: Red Bank fm, Arneytown (Monmouth County, NJ)
13: Red Bank fm, Middletown (Monmouth County, NJ)
14: Red Bank fm, Middletown (Monmouth County, NJ)
15: Tinton fm, Tinton Falls (Monmouth County, NJ)
16: Matawan fm, Bowie (Prince Georges County, MD)
17: Matawan fm, Bowie (Prince Georges County, MD)
18: Matawan fm, Pigeon House Corner (Prince Georges County, MD)
19: Matawan fm, Pigeon House Corner (Prince Georges County, MD)
20: Matawan fm, Jones Township (Anne Arundel County, MD)
21: Severn fm, Stillpond (Kent County, MD)
22: Severn fm, Glenarden (Prince Georges County, MD)
23: Severn fm, Oxen Hill (Prince Georges County, MD)

Collection 1

Locality: streambank exposures along a tributary of Cheesequake Creek; Old Bridge Township, Middlesex County, NJ (site 101 of Weller, 1907)
Grid Coordinates: 40 Deg. 25 Min. 31 Sec. North
74 Deg. 16 Min. 16 Sec. West
Altitude: 50 Ft.
Formation: upper Merchantville (specimens collected *in situ* from uppermost 1.0 meter)
Matrix: unweathered, glauconitic clay containing many horizons of large, rounded siderite concretions
Collection Date: 1994
Preservation: clay molds and casts; molds and casts in siderite concretions
Collector(s): D. Kuehne

Faunal List:

Ichnofossil
Unidentified burrows

Echinoidea
Catopygus pusillus Clark

Pelecypoda
Nucula slackiana (Gabb)
Nemodon sp.
Cucullaea antrosa Morton
Inoceramus proximus Tuomey
Syncyclonema conradi (Whitfield)
Camptonectes bellisculptus (Conrad)
Neithea quinquecostata (Sowerby)
Pterotrigonia thoracica (Morton)
Crassatella lintea? Conrad
Granocardium tenuistriatum (Whitfield)
Cymbophora lintea (Conrad)
Linearia metastriata Conrad
Etea carolinensis aspera (Stephenson)
Aphrodina tippana jerseyensis Richards
Cyprimeria sp.
Legumen ellipticum Conrad
Panopea decisa Conrad
Cymella bella texana Stephenson
Liopistha alternata Weller

Gastropoda
Gyrodes cf. *G. petrosus* (Morton)
Turritella merchantvillensis Weller
Arrhoges lobata (Wade)
Pugnellus sp.
Pyrifusus sp.
Volutomorpha cf. *V. conradi* (Gabb)
Cancellaria sp.
Drilluta? sp.

Scaphopoda
Dentalium subarcuatum Conrad

Cephalopoda
Baculites ovatus Say
Placenticeras placenta (DeKay)

Crustacea
Necrocarcinus rathbunae Roberts

Collection 2

Locality: eroded hillside behind the New Jersey Transit bus terminal, site of the former Graham Brickyard; Maple Shade, Burlington County, NJ (site 16 of Richards et al., 1958)
Grid Coordinates: 39 Deg. 57 Min. 29 Sec. North
74 Deg. 59 Min. 22 Sec. West
Altitude: 30 Ft.
Formation: upper Merchantville (specimens collected *in situ*)
Matrix: sandy, glauconitic clay (weathered near the surface) containing many horizons of small, rounded siderite concretions
Collection Date: 1983-1984
Preservation: clay molds and casts; molds and casts in siderite concretions
Collector(s): D. Kuehne

Faunal List:

Annelida
Hamulus sp.
Longitubus lineatus (Weller)

Echinoidea
Hemiaster sp.

Pelecypoda
Nucula slackiana (Gabb)
Nemodon sp.
N. eufaulensis (Gabb)
Cucullaea neglecta Gabb
Striarca sp.
Glycymeris mortoni (Conrad)
Pinna laqueata Conrad
Pteria? sp.
P. petrosa (Conrad)
Gervillia ensiformis (Conrad)
Inoceramus proximus Tuomey
Camptonectes bellisculptus (Conrad)
Neithea quinquecostata (Sowerby)
Anomia argentaria Morton
Paranomia scabra (Morton)
Pterotrigonia eufaulensis (Gabb)
Crassatella sp.
Granocardium tenuistriatum (Whitfield)
Linearia metastriata Conrad
Veniella conradi Morton

Aphrodina tippana jerseyensis Richards
Cyprimeria sp.
Legumen concentricum Stephenson
Panopea decisa Conrad
Pholadomya occidentalis Morton
Anatimya anteradiata Conrad
Liopistha protexta (Conrad)
Clavagella armata Morton

Gastropoda
Euspira halli (Gabb)
Gyrodes supraplicatus (Conrad)
Xenophora leprosa (Morton)
Turritella merchantvillensis Weller
Anchura sp.
Anchura rostrata (Gabb)
Arrhoges lobata (Wade)
Rostellites texturatus Whitfield
Volutomorpha? sp.
Volutomorpha conradi (Gabb)

Scaphopoda
Dentalium subarcuatum Conrad

Cephalopoda
Baculites ovatus Say
Hoploscaphites hippocrepis (DeKay)
Placenticeras placenta (DeKay)

Crustacea
Protocallianassa mortoni (Pilsbry)

Collection 3

Locality: clay pit (now inactive and water-filled); Deptford, Camden County, NJ (site 6 of Kuehne, 1993)
Grid Coordinates: 39 Deg. 48 Min. 46 Sec. North
75 Deg. 07 Min. 47 Sec. West
Altitude: 90 Ft.
Formation: Woodbury formation (specimens mostly surface collected)
Matrix: unweathered, micaceous, dark-gray clay
Collection Date: ca. 1986
Preservation: original shell material
Collector(s): D. Clements and E. Gilmore

Faunal List:

Coelenterata
Trochocyathus woolmani Vaughan

Annelida
Serpula sp.
Hamulus sp.

Pelecypoda
Nucula slackiana (Gabb)
Nemodon eufaulensis (Gabb)
Cucullaea sp.
Striarca haddonfieldensis (Stephenson)
Glycymeris mortoni (Conrad)
Pinna laqueata Conrad
Gervillia ensiformis (Conrad)
Neithea quinquecostata (Sowerby)
Anomia argentaria Morton
Lima reticulata Lyell and Forbes
Amphidonte sp.
Exogyra costata spinifera Stephenson
Exogyra ponderosa Roemer
Cubitostrea tecticosta (Gabb)
Ostrea plumosa Morton
Agerostrea mesenterica (Morton)
Pterotrigonia eufaulensis (Gabb)
Lucina parva Stephenson
Vetericardiella n. sp.
V. crenilirata (Conrad)
Crassatella spp.
Granocardium dumosum (Conrad)
Veniella conradi Morton
Aphrodina tippana jerseyensis Richards
Cyprimeria depressa (Conrad)
Caestocorbula bisulcata (Conrad)
C. crassiplica (Gabb)
Martesia sp.

Gastropoda
Haustator quadrilira (Johnson)
Turritella sp.
Odontofusus sp.

Cephalopoda
Placenticeras placenta (DeKay)

Crustacea
Hoploparia gabbi Pilsbry

Collection 4

Locality: streambank exposures along a small stream which empties into a tributary of Oldmans Creek; one mile southwest of Swedesboro, Gloucester County, NJ (site 177 of Weller, 1907)
Grid Coordinates: 39 Deg. 44 Min. 02 Sec. North
75 Deg. 20 Min. 55 Sec. West
Altitude: 70 Ft.
Formation: Marshalltown formation (specimens collected *in situ*)
Matrix: unweathered, clayey, glauconitic sand
Collection Date: 1989
Preservation: original shell material
Collector(s): D. Kuehne

Stratigraphic Section (adapted from Gallagher, 1993; reading upwards from base):

Description	Thickness	Total
Olive-gray (5 Y 3/2), clayey, quartzose, glauconitic sand with greenish-black (5 GY 4/1) mottling and shells throughout; prominent shell beds at 43 cm and 1.3 m (Marshalltown formation)	0.5 m	0.5
Dark yellowish-brown (10 YR 4/2) clayey, glauconitic sand with moderate reddish-brown (10 R 4/6) mottling; small, rounded, siderite concretions and abundant molluscan steinkerns (Marshalltown formation)	0.5	2.0
Dark yellowish-orange (10 YR 6/6) to light brown (5 YR 5/6) silty clay which grades upward into light olive-brown (5 Y 5/6) clayey sand with light brown (5 YR 5/6) mottling (Wenonah formation)	0.5	2.5

Faunal List:

Annelida
Serpula circularis Weller
Hamulus wenonahanus Howell

Pelecypoda
Nucula percrassa Conrad
Cucullaea sp.
Camptonectes belliscultus (Conrad)
Neithea quinquecostata (Sowerby)
Anomia argentaria Morton
Paranomia scabra (Morton)
Pycnodonte convexa (Say)
Exogyra ponderosa Roemer
Gryphaeostrea vomer (Morton)
Cubitostrea tecticosta (Gabb)
Ostrea sp.
O. plumosa Morton
Agerostrea falcata (Morton)
Lopha panda (Morton)
Pterotrigonia thoracica (Morton)
Lucina swedesboroensis Weller
Unicardium umbonata (Whitfield)
Crassatella lintea (Conrad)
C. subplana (Conrad)
Granocardium sp.
G. tenuistriatum (Whitfield)
Etea carolinensis aspera (Stephenson)
Veniella conradi Morton
Aphrodina eufaulensis (Conrad)
Cyprimeria excavata (Morton)
Caestocorbula crassiplica (Gabb)

Gastropoda
Turritella sp.
T. marshalltownensis Weller
T. quadrilira Johnson
Anchura sp.
Pyropsis sp.

Cephalopoda
Baculites ovatus Say

Collection 5

Locality: streambank exposures along a tributary of Mantua Creek in the "Oak Valley" neighborhood of Deptford twp; near Wenonah, Gloucester County, NJ (locality 36 of Gallagher, 1984)
Grid Coordinates: 39 Deg. 48 Min. 07 Sec. North
75 Deg. 09 Min. 54 Sec. West
Altitude: 50 Ft.
Formation: Marshalltown formation (specimens collected *in situ*)
Matrix: unweathered, micaceous, glauconitic, dark-gray, sandy clay
Collection Date: 1994
Preservation: clay molds and casts
Collector(s): D. Kuehne, E. Gilmore

Faunal List:

Porifera
Cliona sp.

Annelida
Serpula sp.

Pelecypoda
Nucula slackiana (Gabb)
Nuculana pinnaformis (Gabb)
Nemodon brevifrons Conrad
Cucullaea spp.
Neithea quinquecostata (Sowerby)
Anomia argentaria Morton
Paranomia scabra (Morton)
Lima reticulata Lyell & Forbes
Pycnodonte convexa (Say)
Exogyra sp.
Gryphaeostrea vomer (Morton)
Ostrea sp.
Pterotrigonia thoracica (Morton)
Crassatella sp.
Granocardium tenuistriatum (Whitfield)
Pleuriocardia cf. *P. ripleyana* (Conrad)
Linearia spp.
Etea carolinensis Conrad
Veniella conradi Morton
Thracia tenuis (Whitfield)

Gastropoda
Gyrodes cf. *G. supraplicatus* (Conrad)
Napulus? sp.
Bellifusus medians (Whitfield)
Avellana bullata (Morton)
Cinulia cf. *C. naticoides* (Gabb)
Drilluta? spp.

Scaphopoda
Dentalium sp.

Collection 6

Locality: streambank exposures along a small tributary of Mantua Creek near the intersection of Broadway and Berkeley Roads, behind the K-Mart shopping plaza; Mantua, Gloucester County, NJ (see Clements, 1989)
Grid Coordinates: 39 Deg. 47 Min. 24 Sec. North
75 Deg. 10 Min. 42 Sec. West
Altitude: 45 Ft.
Formation: Marshalltown formation (specimens collected *in situ*)
Matrix: weathered, glauconite sand
Collection Date: 1994
Preservation: sandy molds and casts
Collector(s): D. Kuehne, E. Gilmore

Faunal List:

Echinoidea
Indentified spines

Pelecypoda
Cucullaea sp.
Glycymeris mortoni (Conrad)
Neithea quinquecostata (Sowerby)
Anomia argentaria Morton
Paranomia scabra (Morton)
Lima reticulata Lyell & Forbes

Pycnodonte convexa (Say)
Exogyra ponderosa Roemer
Gryphaeostrea vomer (Morton)
Agerostrea falcata (Morton)
Pterotrigonia thoracica (Morton)
Unicardium umbonata (Whitfield)
Granocardium tenuistriatum (Whitfield)
Cymbophora sp.
Etea carolinensis Conrad
Veniella conradi Morton
Aphrodina tippana jerseyensis Richards
Panopea decisa Conrad

Gastropoda
Euspira halli (Gabb)
Gyrodes cf. *G. supraplicatus* (Conrad)
Turbinopsis sp.
Anchura? sp.
Pyrifusus? sp.

Scaphopoda
Dentalium sp.

Collection 7

Locality: streambank exposure along Big Brook, about 100 meters upstream from the Hillsdale Road bridge; Marlboro Twp, Monmouth County, NJ
Grid Coordinates: 40 Deg. 19 Min. 10 Sec. North
74 Deg. 12 Min. 53 Sec. West
Altitude: 80 Ft.
Formation: upper Wenonah formation (specimens collected *in situ* from uppermost 1.0 meter)
Matrix: unweathered, micaceous, dark-gray, sandy clay
Collection Date: Spring, 1996
Preservation: original shell material
Collector(s): D. Kuehne

Faunal List:

Coelenterata
Trochocyathus woolmani Vaughan

Annelida
Hamulus sp.

Pelecypoda
Nucula slackiana (Gabb)
Nuculana whitfieldi Gardner
Striarca sp.
Lycettia cf. *L. tippana* (Conrad)
Pteria sp.
Inoceramus proximus Tuomey
Camptonectes burlingtonensis (Gabb)
Chlamys quinquenarius (Conrad)
Flemingostrea subspatulata (Forbes)
Agerostrea falcata (Morton)
Pterotrigonia eufaulensis (Gabb)
Crassatella transversa (Gabb)
Granocardium sp.
Cymbophora appressa (Gabb)
Leptosolen biplicata Conrad
Tellina sp.
T. gabbi (Gardner)
Linearia metastriata Conrad
Etea carolinensis aspera (Stephenson)
Tenea parilis? (Conrad)
Veniella conradi Morton
Aphrodina sp.
Legumen ellipticum Conrad
Pholadomya sp.
Cymella bella sp.

Gastropoda
Turritella sp.
Gyrodes sp.
Pugnellus sp.
Napulus sp.

Cephalopoda
Placenticeras sp.
Didymoceras sp.

Collection 8

Locality: small erosional gully adjoining Crosswicks Creek; about 0.5 miles southeast of Walnford, Monmouth County, NJ
Grid Coordinates: 40 Deg. 07 Min. 45 Sec. North
74 Deg. 33 Min. 08 Sec. West
Altitude: 100 Ft.

Formation: upper Wenonah formation (specimens collected *in situ* from upper 2.0 meters)
Matrix: unweathered, micaceous, dark-gray, sandy clay
Collection Date: Spring, 1996
Preservation: clay molds and casts
Collector(s): D. Kuehne

Faunal List:

Pelecypoda
Nuculana whitfieldi Gardner
Postligata sp.
Inoceramus proximus Tuomey
Syncyclonema cf. *S. simplicium* (Conrad)
Chlamys quinquenarius (Conrad)
Lima pelagica Morton
Agerostrea falcata (Morton)
Pterotrigonia sp.
Crassatella transversa (Gabb)
Granocardium sp.
G. cf. *G. ripleyanum* (Conrad)
G. tenuistriatum (Whitfield)
Cymbophora appressa (Gabb)
Tellina sp.
Linearia metastriata Conrad
Etea carolinensis aspera (Stephenson)
Legumen ellipticum Conrad
Caestocorbula crassiplica (Gabb)

Collection 9

Locality: erosional gulley adjoining the west bank of a small tributary which empties into the south branch of the Raccoon Creek; about 1.0 mile west of Mullica Hill, Gloucester County, NJ
Grid Coordinates: 39 Deg. 43 Min. 55 Sec. North
75 Deg. 13 Min. 23 Sec. West
Altitude: 70 Ft.
Formation: upper Mt. Laurel and basil Navesink formations (specimens collected *in situ*)
Matrix: pebbly sand with some glauconite (Mt. Laurel formation); semi-indurated, glauconitic sand (Navesink formation)
Collection Date: 1995
Preservation: molds and casts
Collector(s): D. Kuehne

Stratigraphic Section (reading upwards from base):

Description	Thickness	Total
Weathered, pale yellowish orange (10 YR 8/6), pebbly sand containing some glauconite and specimens of *Neithea quinquecostata*, *Ostrea plumosa*, and *Belemnitella americana* (Mt. Laurel formation)	0.8 m	0.8
Mostly weathered, pale yellowish orange (10 YR 8/6), pebbly, glauconitic sand containing abundant molluscs, especially *Neithea quinquecostata* and *Pycnodonte convexa* (Mt. Laurel formation)	0.5	1.3
Olive-black (5 Y 2/1) semi-indurated, glauconitic sand containing scattered pebbles and abundant molluscan steinkerns, especially *Pycnodonte convexa*, *Plicatula mullicaensis*, *Agerostrea mesenterica*, *Cucullaea tippana*, *Chlamys venustus*, and *Belemnitella americana* (Navesink formation)	0.65	1.95

Grayish olive-green (5 GY 3/2) clayey, glauconitic sand (indurated in places) containing scattered specimens of *Pycnodonte convexa* (Navesink formation)	0.8	2.75

Faunal List (Mt. Laurel formation)**:**

Pelecypoda
Neithea quinquecostata (Sowerby)
Plicatula mullicaensis Weller
Spondylus echinata (Morton)
Pycnodonte convexa (Say)
Exogyra cancellata Stephenson
Gryphaeostrea vomer (Morton)
Ostrea plumosa Morton

Gastropoda
Euspira halli (Gabb)

Cephalopoda
Belemnitella americana (Morton)

Echinoidea
Cardiaster sp.

Faunal List (Navesink formation)**:**

Porifera
Cliona cretacica Fenton & Fenton

Annelida
Hamulus sp.

Pelecypoda
Cucullaea antrosa Morton
C. tippana Conrad
Inoceramus? sp.
Chlamys venustus (Morton)
Neithea quinquecostata (Sowerby)
Plicatula mullicaensis Weller
Pycnodonte convexa (Say)
Exogyra costata Say
Gryphaeostrea vomer (Morton)
Agerostrea mesenterica (Morton)
Pterotrigonia n. sp.
Crassatella vadosa (Morton)
Granocardium tenuistriatum (Whitfield)
Protocardia spillmani (Conrad)
Veniella conradi Morton

Gastropoda
Gyrodes sp.
Turritella sp.
Anchura sp.
Pyropsis sp.
Volutomorpha? sp.

Cephalopoda
Belemnitella americana (Morton)

Collection 10

Locality: small stream which dissects hillside and flows into Mullica pond, east of Route 45 and south of Route 222; Mullica Hill, Gloucester County, NJ (site 6 of Gallagher, 1993)
Grid Coordinates: 39 Deg. 43 Min. 55 Sec. North
75 Deg. 13 Min. 23 Sec. West
Altitude: 70 Ft.
Formation: basil Navesink formation (specimens collected *in situ* from lowermost 1.5 meters)
Matrix: semi-indurated, glauconitic, sandy clay
Collection Date: 1994
Preservation: molds and casts
Collector(s): D. Kuehne

Stratigraphic Section (adapted from Gallagher, 1993; reading upwards from base)**:**

Description	Thickness	Total
Brownish-black (5 YR 2/1) to olive-black (5 Y 2/1) semi-indurated, glauconitic sand containing scattered pebbles and abundant molluscan steinkerns (Navesink formation)	1.0 m	1.0

Yellow-green (5 GY 5/2) to grayish olive-green (5 GY 3/2) clayey, glauconitic sand with indurated layer containing abundant *Exogyra costata* and *Pycnodonte convexa* at 1.7 m (Navesink formation)	1.0	2.0
Greenish-black (5 G 2/1) clayey, glauconitic sand grading upwards into dark yellowish-brown (10 YR 4/2) sandy, glauconitic clay with greenish-black (5 GY 2/1) mottling (Navesink formation)	3.9	5.9
Grayish olive-green (5 GY 3/2) clayey, glauconitic sand; *Pycnodonte* shellbed at 6.1 m (Hornerstown formation)	0.6	6.5

Faunal List:

Pelecypoda
Cucullaea tippana Conrad
Pteria cf. *P. laripes* (Morton)
Chlamys venustus (Morton)
Plicatula mullicaensis Weller
Anomia argentaria Morton
Pycnodonte convexa (Say)
Exogyra costata Say
Gryphaeostrea vomer (Morton)
Agerostrea mesenterica (Morton)
Pterotrigonia cerulia (Whitfield)
P. cf. *P. eufaulensis* (Gabb)
Crassatella vadosa (Morton)
Protocardia spillmani (Conrad)
Anatimya anteradiata Conrad

Gastropoda
Scala cyclostoma Gabb
Euspira halli (Gabb)
Gyrodes abyssinus (Morton)
G. petrosus (Morton)
Anchura sp.
A. rostrata (Gabb)
Napulus sp.
Pyrifusus? sp.
Bellifusus slacki (Gabb)
Volutomorpha sp.
Turricula cf. *T. biacuminata* Wade

Cephalopoda
Baculites ovatus Say
Belemnitella americana (Morton)
Eutrephoceras dekayi (Morton)

Collection 11

Locality: base of bluff facing Raritan Bay east of the Atlantic Highlands marina; Atlantic Highlands, Monmouth County, NJ (site 108 of Weller, 1907)
Grid Coordinates: 40 Deg. 24 Min. 45 Sec. North
74 Deg. 01 Min. 29 Sec. West
Altitude: 80 Ft.
Formation: basil Navesink (specimens collected *in situ* from lowermost 0.5 meter)
Matrix: pebbly, glauconitic sand
Collection Date: 1969-1990
Preservation: molds and casts
Collector(s): R. Johnson

Stratigraphic Section (adapted from Gallagher, 1993; reading upwards from base):

Description	Thickness	Total
Light olive gray (5 Y 5/2) to olive gray (5 Y 3/2) micaceous, glauconitic, quartz sand with siderite concretions at 0.0 m (Navesink formation)	0.65 m	0.65

Greenish-black (5 G 2/1 to 5 GY 2/1) glauconitic sand; small quartz pebbles in basal portion and shell beds at 0.5-0.7 m and 0.8-0.9 m (Navesink formation)	0.45	0.95
Greenish-black (5 GY 2/1 to 5 G 2/1), clayey, glauconitic sand with extensive mottling (Navesink formation)	1.25	2.2
Greenish-black (5 GY 2/1 to 5 G 2/1), clayey, glauconitic sand (Navesink formation)	5.8	8.0
Greenish-black (5 GY 2/1), micaceous, glauconitic sand with abundant, large, flat, siderite concretions (Navesink formation)	0.5	8.5
Grayish-black (N2), lignitic, micaceous, sandy clay (Navesink formation)	1.0	9.5
Moderate brown (5 YR 3/4) to dark yellowish-orange (10 YR 6/6), lignitic, micaceous, clayey sand (Navesink formation)	2.5	12.0
Grayish-black (N2) lignitic, micaceous, sandy clay (Red Bank formation: Sandy Hook member)	2.25	14.25
Dark yellowish-orange (10 YR 6/6), micaceous, clayey quartz sand (Red Bank formation: Shrewsbury member)	1.25	15.5

Faunal List:

Porifera
Cliona microtuberum Stephenson

Annelida
Longitubus lineatus (Weller)
Serpula sp.

Echinoidea
Catophygus williamsi Clark
Hardouinia sp.
Cardiaster marylandicus Clark
Hemiaster delawarensis Clark

Brachiopoda
Lingula subspatulata Hall and Meek
Choristothyris plicata (Say)

Pelecypoda
Nuculana sp.
Arca rostellata Morton
Nemodon angulatum (Gabb)
N. eufaulensis (Gabb)
Cucullaea antrosa Morton
C. tippana Conrad
Lycettia sp.
Inoperna carolinensis (Conrad)
Pinna laqueata Conrad
Gervillia ensiformis (Conrad)
Inoceramus sp.
Syncyclonema conradi (Whitfield)
Neithea quinquecostata (Sowerby)
Spondylus echinata (Morton)
Paranomia scabra (Morton)
Lima pelagica Morton
L. reticulata Forbes
Pycnodonte convexa (Say)
Exogyra n. sp.
E. cancellata Stephenson
E. costata Say
Gryphaeostrea vomer (Morton)
Agerostrea cf. *A. falcata* (Morton)
Pterotrigonia thoracica (Morton)
Unicardium umbonata (Whitfield)
Crassatella vadosa (Morton)
Granocardium sp.
Protocardia sp.
Cymbophora appressa (Gabb)
Leptosolen sp.
Tellina sp.
Linearia tenuis (Whitfield)
Solyma lineolatus Conrad

Etea carolinensis aspera (Stephenson)
Tenea pinguis (Conrad)
Veniella conradi Morton
V. elevata conrad
Corbicula? sp.
Aphrodina tippana (Conrad)
Cyprimeria sp.
Icanotia pulchra Wade
Legumen ellipticum Conrad
Gastrochaena whitfieldi Weller
Panopea decisa Conrad
Clavipholas pectrosa (Conrad)
Xylophagella irregularis (Gabb)
Pholadomya sp.
Laternula robusta Stephenson
Anatimya lata (Whitfield)
Cymella bella texana Stephenson
Liopistha inflata Whitfield
L. protexta (Conrad)
Clavagella armata Morton

Gastropoda
Arrhoges sp.
Anchura? sp.
Volutomorpha mutabilis? Wade
Turbinella? sp.
Cypraea sp.
Turritella vertebroides Morton
Ornopsis? sp.
Acteon sp.
Nonacteonina sp.
Bellifusus? sp.
Anisomyon sp.
Epitonium sp.
Weeksia sp.
Euspira sp.
Gyrodes sp.
Capulus spangleri Henderson
Xenophora leprosa (Morton)
X. sp.
Laxispira sp.
Cerithium sp.
Pterocerella sp.
Hercorhynchus sp.
Napulus sp.
Pyropsis sp.
Sargana sp.
Ellipsoscapha mortoni (Forbes)

Cephalopoda
Baculites claviformis Stephenson
B. ovatus Say
Belemnitella americana (Morton)
Nostoceras draconis Stephenson
N. helicinum (Schumard)
N. hyatti Stephenson
N. mendryki Cobban
N. pauper (Whitfield)
N. stantoni Hyatt
Axonoceras angolanum Haas
Exiteloceras oronense (Lewy)
Didymoceras navarroense (Shumard)
Hoploscaphites plenus (Meek)
H. pumilus (Stephenson)
Pachydiscus neubergicus raricostatus Blaszkiewicz
Eutrephoceras dekayi (Morton)

Crustacea
Hoploparia gabbi Pilsbry
Protocallianassa mortoni (Pilsbry)
Cretocoranina? sp.
Necrocarcinus? sp.

Collection 12

Locality: streambank outcrops along Crosswicks Creek; one mile east of Arneytown, Monmouth County, NJ (see Gallagher, 1984, p. 21)
Grid Coordinates: 40 Deg. 05 Min. 52 Sec. North
74 Deg. 32 Min. 36 Sec. West
Altitude: 65 Ft.
Formation: Glauconitic facies of the Red Bank formation (specimens collected *in situ* from lowermost 2.0 meters)
Matrix: unweathered, partially indurated (in places), dark-gray clay
Collection Date: 1994
Preservation: clay molds and casts; some original shell material
Collector(s): D. Kuehne

Faunal List:

Pelecypoda
Cucullaea neglecta Gabb
Chlamys venustus (Morton)
Lima sp.
Pycnodonte convexa (Say)
Exogyra costata Say
Ostrea? sp.
Granocardium kummeli (Weller)

Tellina sp.
Veniella conradi Morton

Gastropoda
Euspira sp.

Turritella sp.

Haustator sp.
Anchura sp.
Pyropsis sp.

Cephalopoda
Eutrephoceras dekayi (Morton)

Collection 13

Locality: streambank exposures along the headwaters of Mill Brook; Middletown Twp, Monmouth County, NJ
Grid Coordinates: 40 Deg. 23 Min. 47 Sec. North
74 Deg. 06 Min. 56 Sec. West
Altitude: 90 Ft.
Formation: Sandy Hook Member of the Red Bank formation (specimens collected *in situ*)
Matrix: unweathered, micaceous, dark-gray, glauconitic, sandy clay
Collection Date: ca. 1984
Preservation: original shell material
Collector(s): N. Sohl

Faunal List (from Sohl, 1984):

Coelenterata
Micrabacia spp.

Bryozoa
Unidentified branching and encrusting types

Annelida
Serpula sp.
Hamulus onyx Morton

Echinoidea
Unidentified species

Pelecypoda
Nucula amica Gardner
N. cunifrons Conrad
Nuculana whitfieldi (Gardner)
Perissonata protexta (Conrad)
P. littlei Gardner
Nemodon eufaulensis (Gabb)
N. stantoni Gardner
Striarca saffordi (Gardner)
Cucullaea littlei Gabb
Limopsis sp.
Glycymeris sp.
Postligata wordeni Gardner
Crenella serica Conrad
Lithophaga sp.
Pteria rhombica Gardner
Gervillia ensiformis (Conrad)
Camptonectes bubonis (Stephenson)
Chlamys venustus Morton
Anomia argentaria Morton
Lima reticulata Lyell & Forbes
Pycnodonte convexa (Say)
Exogyra costata Say
Gryphaeostrea vomer Morton
Cubitostrea tecticosta (Gabb)
Agerostrea mesenterica (Morton)
Pterotrigonia angulicostata (Gabb)
P. eufaulensis (Gabb)
Lucina? *linearia* (Stephenson)
L. parvetineata Schumard
Unicardium sp.
Vetericardiella crenalirata (Conrad)
Uddenia texana Stephenson
Granocardium kummeli (Weller)
Pleuriocardia eufaulensis (Conrad)
Cymbophora berryi (Gardner)
C. wordeni (Gardner)
Tellinimera buboana Stephenson
Aenona eufaulensis (Conrad)
Veniella conradi (Morton)
Tenea parilis Conrad
Legumen ellipticum Conrad
Corbula monmouthensis Gardner
Caestocorbula crassiplica (Gabb)
C. percompressa Gardner
Opertochasma sp.
Liopistha protexta Conrad

Gastropoda
Ataphrus n. sp.
Urceolabrum turberculatum callistrum Harbison
Margaritella pumila Stephenson
Haustator trilira (Conrad)
Turritella vertebroides Morton
Cerithium aff. *C. weeksi* Wade

Striaticostatum sparsum Sohl
Xenophora leprosa (Morton)
Arrhoges cf. *A. lobata* (Wade)
Anchura cf. *A. abrupta* Conrad
Gyrodes supraplicatus (Conrad)
Euspira rectilabrum (Conrad)
Amaurellina stephensoni (Wade)
Tuba sp.
Sargana sp.
Stantonella sp.
Bellifusus curvicostatus (Wade)
Hercorhyncus sp.
Napulus octoliratus Conrad
Paleofusimitra sp.
Volutomorpha sp.
Paladmete laevis Sohl
P. cancellaria (Conrad)
Remnita cf. *R. biacuminata* (Wade)
Acteon sp.
Ringicula clarki Gardner
Oligoptycha sp.
Ellipsoscapha mortoni (Forbes)

Scaphopoda
Dentalium leve Stephenson

Cephalopoda
Eutrephoceras dekayi (Morton)
Baculites carinatus Morton
Discoscaphites conradi (Morton)

Collection 14

Locality: streambank exposures along Poricy Brook; Middletown Twp, Monmouth County, NJ
Grid Coordinates: 40 Deg. 22 Min. 08 Sec. North
74 Deg. 07 Min. 02 Sec. West
Altitude: 75 Ft.
Formation: Sandy Hook Member of the Red Bank formation (specimens collected *in situ*)
Matrix: unweathered, micaceous, dark-gray, glauconitic, sandy clay
Collection Date: ca. 1984
Preservation: original shell material
Collector(s): N. Sohl

Faunal List (from Sohl, 1984)**:**

Coelenterata
Trochocyathus sp.
Micrabacia sp.

Bryozoa
Inidentified branching type

Annelida
Hamulus onyx Morton

Pelecypoda
Nucula percrassa Conrad
N. amica Gardner
Nuculana whitfieldi (Gardner)
Nemodon eufaulensis (Gabb)
Striarca saffordi (Gardner)
Limopsis sp.
Crenella serica Conrad
C. elegantula Meek & Hayden
Modiolus sedesclaris Gardner
Gervillia ensiformis (Conrad)
Syncyclonema simplicium (Conrad)
Camptonectes bubonis (Stephenson)
Chlamys venustus Morton
Anomia argentaria Morton
Lima reticulata Lyell & Forbes
Cubitostrea tecticosta (Gabb)
Agerostrea mesenterica (Morton)
Pterotrigonia eufaulensis (Gabb)
Lucina? *linearia* (Stephenson)
Vetericardiella crenalirata (Conrad)
Cymbophora berryi (Gardner)
Veniella conradi (Morton)
Corbula monmouthensis Gardner
Caestocorbula crassiplica (Gabb)

Gastropoda
Haustator bilira (Stephenson)
Turritella vertebroides Morton
Cerithium aff. *C. weeksi* Wade
Morea marylandica Gardner
Drilluta sp.
Napulus sp.
Oligoptycha sp.

Scaphopoda
Dentalium leve Stephenson

Cephalopoda
Baculites sp.

Collection 15

Locality: Streambed and streambank exposures along Pine Brook, downstream from Tinton Avenue; Tinton Falls, Monmouth County, NJ (site 110 of Weller, 1907)
Grid Coordinates: 40 Deg. 18 Min. 15 Sec. North
74 Deg. 06 Min. 07 Sec. West
Altitude: 35 Ft.
Formation: Tinton formation (specimens collected *in situ*)
Matrix: Pebbly, glauconitic sandstone (cemented with siderite)
Collection Date: ca. 1984
Preservation: Molds and casts; some original shell material
Collector(s): N. Sohl

Stratigraphic Section (adapted from Gallagher, 1993; reading upwards from base):

Description	Thickness	Total
Dusky yellowish-green (10 GY 3/2), fossiliferous, massive, medium to course-grained glauconitic sandstone	0.5 m	0.5
Dark reddish-brown (10 R 3/4) to olive-gray (5 Y 3/2), fossiliferous, poorly sorted, pebbly, glauconitic sandstone with dark yellowish-orange (10 YR 6/6) iron oxide streaks	1.5	2.0
Highly weathered glauconitic sandstone	0.5	2.5

Faunal List (from Sohl, 1984):

Porifera
Cliona sp.

Bryozoa
Unidentified branching type

Pelecypoda
Cucullaea capax Conrad
Glycymeris rotundata (Gabb)
Pteria sp.
Syncyclonema simplicium (Conrad)
Camptonectes sp.
Chlamys venustus Morton
Lima reticulata Lyell & Forbes
Pycnodonte convexa (Say)
Exogyra sp.
Gryphaeostrea vomer Morton
Ostrea plumosa Morton
Agerostrea mesenterica (Morton)
Pterotrigonia angulicostata (Gabb)
Protocardia sp.
Granocardium kummeli (Weller)
Cymbophora sp.
Veniella conradi (Morton)
Glossus sp.

Gastropoda
Calliomphalus americanus Wade
C. microancelli Stephenson
Haustator bilira (Stephenson)
Turritella sp.
Striaticostatum sillimani (Morton)
Arrhoges cf. *A. lobata* (Wade)
Euspira rectilabrum (Conrad)
Pyrifusus sp.
Drilluta cf. *D. buboanus* Sohl
Hercorhynchus pagodaformis Sohl
Pyropsis spp.
Anisomyon? sp.

Cephalopoda
Sphenodiscus lobatus (Toumey)

Crustacea
Unidentified appendages

Collection 16

Locality: streambank exposure along a tributary of the Patuxent River, behind the University of Maryland Science and Technology Center; Bowie, Prince Georges County, MD (see Glaser, 1986, p. 68)

Grid Coordinates: 38 Deg. 57 Min. 57 Sec. North
76 Deg. 42 Min. 38 Sec. West

Altitude: 55 Ft.

Formation: uppermost Matawan formation (specimens collected *in situ* from uppermost 0.5 meters)

Matrix: unweathered, micaceous, medium-gray, clayey sand; contains selenite crystals

Collection Date: 1994

Preservation: clay molds and casts; some pyritized shell material

Collector(s): D. Kuehne

Stratigraphic Section (reading upwards from base):

Description	Thickness	Total
Compact, medium-gray, micaceous, clayey sand, containing abundant molds and casts of molluscs (uppermost Matawan formation)	0.5 m	0.5
not exposed	0.5	1.0
dark-gray, micaceous, clayey sand (basal Severn formation)	2.5	3.5

Faunal List:

Pelecypoda
Nucula amica Gardner
N. percrassa Conrad
N. slackiana (Gabb)
Nuculana aff. *N. littlii* (Gardner)
N. rostratruncata (Gardner)
N. whitfieldi (Gardner)
Nemodon eufaulensis Conrad
N. cf. *N. stantoni* Gardner
Striarca sp.
Modiolus monmouthensis (Weller)
Anomia argentaria Morton
Lima sp.
Agerostrea mesenterica (Morton)
Pterotrigonia sp.
Crassatella sp.
Granocardium sp.
G. tenuistriatum (Whitfield)
Pleuriocardia sp.
Protocardia spillmani (Conrad)
Cymbophora spp.
Leptosolen biplicata Conrad
Aenona eufaulensis (Conrad)
Tellina spp.
Etea carolinensis Conrad
Tenea parilis (Conrad)
Veniella conradi Morton
Cyprimeria depressa Conrad
Cyclina parva Gardner
Legumen ellipticum Conrad
Caestocorbula foulkei (Lea)
C. aff. *C. terramaria* (Gardner)
Pholas sp.
Diceras sp.
Thracia aff. *T. tenuis* (Whitfield)
Liopistha sp.

Gastropoda
Haustator trilira (Conrad)
Pugnellus sp.

Scaphopoda
Dentalium aff. *D. subarcuatum* Conrad

Collection 17

Locality: Large streambank exposure along White Marsh Branch, a tributary of the Putuxent River, about 200 meters behind the Bowie Racquet and Fitness Club; Bowie, Prince Georges County, MD

Grid Coordinates: 38 Deg. 58 Min. 45 Sec. North
76 Deg. 43 Min. 20 Sec. West
Altitude: 80 Ft.
Formation: Matawan formation (specimens collected *in situ*)
Matrix: unweathered, medium-gray, micaceous, sandy clay
Collection Date: 1994
Preservation: clay molds and casts; some pyritized shell material
Collector(s): D. Kuehne, W. Kuehne
Stratigraphic Section (reading upwards from base):

Description	Thickness	Total
Olive-black (5 Y 2/1), micaceous, thoroughly bioturbated, sandy clay, containing molds and casts of molluscs throughout (upper Severn formation)	5.2m	5.2
Dark-gray (10 YR 3/1), micaceous clay, with orange and yellow mottling due to weathering (upper Severn formation)	0.3	5.5
Brown (10 YR 5/3), highly weathered, sandy clay (Basal Brightseat formation?)	2.0	7.5

Faunal List:

Pelecypoda
Nucula cf. *N. slackiana* (Gabb)
Cucullaea sp.
Syncyclonema simplicium (Conrad)
Pterotrigonia eufaulensis (Gabb)
Crassatella sp.
Linearia metastriata Conrad
Aphrodina tippana Conrad
Legumen ellipticum Conrad

Gastropoda
Gyrodes sp.
Haustator sp.

Scaphopoda
Dentalium aff. *D. subarcuatum* Conrad

Collection 18

Locality: small streambed exposure located close to the source of a small stream which empties into a tributary of the Patuxent River; 0.75 miles southeast of Pigeon House Corner, Prince Georges County, MD
Grid Coordinates: 38 Deg. 59 Min. 00 Sec. North
76 Deg. 41 Min. 45 Sec. West
Altitude: 90 Ft.
Formation: upper Matawan formation (specimens collected *in situ*)
Matrix: medium-gray, micaceous, bioturbated, sandy clay; contains selenite crystals where unweathered
Collection Date: 1994
Preservation: clay molds and casts
Collector(s): D. Kuehne

Faunal List:

Pelecypoda
Nucula cf. *N. slackiana* (Gabb)
Nuculana sp.
Lucina sp.
Crassatella sp.
Pleuriocardia sp.
Cymbophora sp.
Tellina sp.

Gastropoda
Turritella sp.
Gyrodes sp.

Collection 19

Locality: small streambank exposure along a tributary of the Patuxent River; 0.70 miles southeast of Pigeon House Corner, Prince Georges County, MD
Grid Coordinates: 38 Deg. 59 Min. 08 Sec. North
76 Deg. 41 Min. 34 Sec. West
Altitude: 55 Ft.
Formation: Matawan formation (specimens collected *in situ*)
Matrix: medium-gray, micaceous, bioturbated, sandy clay
Collection Date: 1994
Preservation: clay molds and casts
Collector(s): D. Kuehne, W. Kuehne

Faunal List:

Pelecypoda
Cucullaea sp.
Crenella serica Conrad
Exogyra costata Say
Ostrea aff. *O. plumosa* Morton
Agerostrea cf. *A. mesenterica* (Morton)

Gastropoda
Haustator trilira (Conrad)
Pyropsis sp.

Collection 20

Locality: Large bluff on the shore of Round Bay, 0.25 miles north of Swan Point; Jones Township, Anne Arundel County, MD
Grid Coordinates: 39 Deg. 03 Min. 07 Sec. North
76 Deg. 32 Min. 20 Sec. West
Altitude: 20 Ft.
Formation: uppermost Matawan formation (specimens collected *in situ* from uppermost 0.5 meter)
Matrix: olive-gray, micaceous, glauconitic, clayey sand; contains selenite crystals where unweathered
Collection Date: 1994
Preservation: clay molds and casts; some pyrite replacement
Collector(s): D. Kuehne, W. Kuehne

Stratigraphic Section (reading upwards from base):

Description	Thickness	Total
Olive-black (5 Y 2/1), micaceous, thoroughly bioturbated, glauconitic, clayey sand (Matawan formation)	4.5 m	4.5
Olive-black (5 Y 2/1), micaceous, glauconitic, clayey sand, containing molds and casts of molluscs (uppermost Matawan formation)	0.5	5.0
Dark-gray (5 Y 3/1) to olive-gray (5 Y 4/1), micaceous, sandy clay (basal Severn formation)	3.0	8.0
Light-brown, highly weathered, thoroughly bioturbated, clayey sand (Brightseat formation)	1.0	9.0

Faunal List:

Annelida
Longitubus lineatus (Weller)
Filogranula cf. *F. jerseyensis* Howell

Coelenterata
Unidentified species

Pelecypoda
Cucullaea sp.
Pycnodonte sp.
Agerostrea cf. *A. mesenterica* (Morton)
Pterotrigonia cf. *P. bartrami* (Stephenson)
P. eufaulensis (Gabb)
Pleuriocardia sp.
Cymbophora sp.
Veniella conradi Morton
Caestocorbula sp.
Xylophagella irregularis (Gabb)

Gastropoda
Turritella sp.

Collection 21

Locality: streambank exposures along a small tributary of Lloyd Creek; east of Stillpond, Kent County, MD (see Minard, 1974, p. 23)
Grid Coordinates: 39 Deg. 19 Min. 50 Sec. North
76 Deg. 01 Min. 45 Sec. West
Altitude: 40 Ft.
Formation: Severn (specimens collected *in situ*)
Matrix: unweathered, micaceous sandy clay
Collection Date: ca. 1984
Preservation: clay molds and casts
Collector(s): N. Sohl

Faunal List (after Sohl, 1984)**:**

Annelida
Serpula sp.
Hamulus squamosus Gabb

Pelecypoda
Cucullaea capax Conrad
Glycymeris rotundata (Gabb)
Botula conchafodentis (Gardner)
Lithophaga sp.
Syncyclonema simplicium (Conrad)
Anomia argentaria Morton
A. ornata Gabb
Pycnodonte convexa (Say)
Cubitostrea tecticosta (Gabb)
Agerostrea mesenterica (Morton)
Pterotrigonia thoracica? (Morton)
P. eufaulensis moorei (Stephenson)
Crassatella vadosa vadosa Morton
Granocardium sp.
Pleuriocardia eufaulensis (Conrad)
Veniella conradi (Morton)
Eufistulena sp.
Corymya tenuis? Whitfield

Gastropoda
Haustator bilira (Stephenson)
Turritella sp.
T. paravertebroides Gardner
Arrhoges sp.
Pyropsis spp.
Paladmete laevis Sohl
Acteon cicatricosus Sohl

Scaphopoda
Dentalium sp.

Cephalopoda
Baculites sp.
Discoscaphites conradi (Morton)
Sphenodiscus sp.

Crustacea
Unidentified appendages

Collection 22

Locality: streambank exposures along a tributary of Cattail Branch; near Glenarden, Prince Georges County, MD ("Brightseat" locality of Gardner, 1916)
Grid Coordinates: 38 Deg. 54 Min. 36 Sec. North
76 Deg. 52 Min. 03 Sec. West
Altitude: 150 Ft.
Formation: upper Severn (specimens collected *in situ* from uppermost 2.0 meters)
Matrix: unweathered, micaceous, dark-gray, sandy clay, containing large, rounded siderite concretions
Collection Date: ca. 1980-1985

Preservation: original shell material in clay and also in siderite concretions
Collector(s): R. Johnson

Faunal List:

Coelenterata
Micrabacia marylandica Gardner

Annelida
Longitubus lineatus (Weller)
Hamulus squamosus Gabb

Pelecypoda
Nucula slackiana (Gabb)
Nuculana littlii (Gardner)
N. rostratruncata (Gardner)
Nemodon eufaulensis Conrad
N. uandi (Gardner)
Cucullaea deatsvillensis (Stephenson)
Glycymeris mortoni (Conrad)
G. wardeni Conrad
Lycettia tippana (Conrad)
Crenella serica Conrad
Lithophaga carolinensis (Conrad)
Modiolus? sp.
Pteria rhombica Gardner
Syncyclonema simplicium (Conrad)
Camptonectes bellisculptus (Conrad)
Anomia forteplicata Gardner
Exogyra costata Say
Gryphaeostrea vomer Morton
Cubitostrea tecticosta (Gabb)
Flemingostrea subspatulata (Forbes)
Agerostrea mesenterica (Morton)
A. monmouthensis (Weller)
Pterotrigonia eufaulensis (Gabb)
Crassatella vadosa Morton
Bathytormus pteropsis (Conrad)
Pleuriocardia eufaulensis (Conrad)
Protocardia spillmani (Conrad)
Cymbophora appressa (Gabb)
C. berryi (Gardner)
Leptosolen biplicata Conrad
Aenona eufaulensis (Conrad)
Linearia carolinensis Conrad
Tellinimera eborea (Conrad)
Tenea pinguis Conrad
Veniella conradi Morton
Aphrodina tippana (Conrad)
Cyprimeria alta Conrad
C. depressa Conrad
Legumen concentricum Stephenson
Gastrochaena whitfieldi Weller
Panopea decisa Conrad
Pholas pectrosa Conrad
Xylophagella irregularis (Gabb)
Anatimya anteradiata Conrad
A. lata (Whitfield)
Liopistha protexta (Conrad)

Gastropoda
Euspira rectilabrum Conrad
Paladmete cancellaria (Conrad)
Gyrodes spillmani Gabb
G. subcarinatus Stephenson
G. supraplicatus (Conrad)
Xenophora leprosa (Morton)
Haustator bilira Stephenson
Turritella sp.
T. tippana Conrad
T. vertebroides Morton
Epitonium sp.
Cerithium sp.
Acirsa flexicostata Sohl
Pyropsis sp.
P. cornutus Sohl
Liopeplum canalis Conrad
L. coronatum Sohl
L. cretaceam (Conrad)
Drilluta distans Conrad
D. major Wade
Fusimilis kummeli Sohl
Bellifusus sp.
B. angulicostata Sohl
B. curicostatus (Wade)
Pyrofusus sp.
Lupira sp.
Deussenia sp.
D. ripleyana Harbison
Hydrotribulus elegans Sohl
Stantonella ripleyana Conrad
Beratra gracilis (Wade)
B. speciosa Sohl
Remera flexicostata Sohl
Graphidula terebriformis Stephenson
Hercorhyncus tippana? Conrad
Arrhoges (Latiala) lobata Wade
Pterocerella sp.
Pugnellus densatus (Conrad)
Morea marylandica Gardner
Napulus fragilis Sohl
Ringicula pulchella Shumard
Ancilla (Ancillus) acutula Stephenson
Remnita biacuminata (Wade)
Urceolabrum tuberculatum Wade

Nudivagus? *cooperensis* Stephenson
Caveola sp.
Anchura sp.
Ornopsis? sp.
Weeksia deplanata (Johnson)
Architectonica? sp.
Acteon linteus (Conrad)
Ellipsoscapha mortoni (Forbes)
Bullopsis cretacea Conrad
Belliscala? sp.

Cephalopoda

Sphenodiscus lenticularis (Owen)
Coahuilites sp.
Discoscaphites conradi gulosus (Morton)
D. conradi conradi (Morton)
Hoploscaphites nebrascensis (Owen)
Baculites carinatus Morton
Glyptoxoceras sp.
Eutrephoceras dekayi (Morton)

Crustacea

Protocallianassa mortoni (Pilsbry)
Hoploparia sp.

Collection 23

Locality: streambank exposures at the head of a small ravine; 1 1/2 miles south of Oxen Hill, Prince Georges County, MD (site F of Baird, 1986)
Grid Coordinates: 38 Deg. 46 Min. 55 Sec. North
76 Deg. 59 Min. 38 Sec. West
Altitude: 130 Ft.
Formation: upper Severn (specimens collected *in situ* from uppermost 2.0 meters)
Matrix: unweathered, medium-gray, micaceous, sandy clay
Collection Date: 1994
Preservation: original shell material in clay and also in siderite concretions
Collector(s): D. Kuehne

Stratigraphic Section (reading upwards from base):

Description	Thickness	Total
Dark-gray (5 Y 4/1), micaceous, sandy clay, containing a prominant horizon of large (up to 0.4 m in length), fossiliferous, irregular, nobby, ferruginous concretions at 2.0 m and mollusc shells throughout; shells are concentrated in ellipse-shaped pods which are scattered throughout this interval (upper Severn formation)	2.4	2.4
Dark-gray (10 YR 3/1), micaceous, sandy clay, occasionally with small pockets of olive-black (5 Y 2/1) glauconitic sand which contain abundant, black, worn, phosphatic pebbles and darkened, reworked shark teeth (uppermost Severn formation)	0.4	2.8
Dark-gray (5 Y 3/1), glauconitic sand containing abundant, black, worn, phosphatic pebbles and darkened shark teeth (Aquia formation)	0.1	2.9
Dark-gray (5 Y 4/1), localized, densely packed, indurated shellbed containing *Meretrix ovata* v. *pyga*, *Venericardia planicosta*, *Crassatella alaeformis*, and *Cucullaea gigantea*, and abundant, black, worn, phosphatic pebbles and darkened shark teeth (Aquia formation)	0.1	3.0

Dark-gray (5 Y 3/1) glauconite sand containing a densely-packed shellbed dominated by *Turritella mortoni*, *Crassostrea compressirostra*, and *Cucullaea gigantea* (Aquia formation)	0.6	3.6
Yellowish-brown (10 YR 5/6), weathered glauconitic sand with orange and yellow mottling (Aquia formation)	1.0	4.6
Yellowish-brown (10 YR 5/6), highly weathered sand (Aquia formation)	2.0	6.6

Faunal List:

Coelenterata
Micrabacia marylandica Gardner

Annelida
Hamulus aff. *H. squamosus* Gabb

Pelecypoda
Nucula slackiana (Gabb)
Nuculana rostratruncata (Gardner)
N. whitfieldi Gardner
Nemodon stantoni Gardner
Striarca sp.
Lycettia tippana (Conrad)
Crenella serica Conrad
Inoperna carolinensis (Conrad)
Syncyclonema simplicium (Conrad)
Anomia argentaria Morton
Exogyra costata Say
E. costata spinifera Stephenson
E. ponderosa Roemer
Ostrea sp.
Agerostrea mesenterica (Morton)
A. monmouthensis (Weller)
Pterotrigonia eufaulensis (Gabb)
Crassatella vadosa Morton
Bathytormus pteropsis (Conrad)
Granocardium cf. *G. tenuistriatum* (Whitfield)
Pleuriocardia eufaulensis (Conrad)
Cymbophora appressa (Gabb)
Aeona eufalensis (Conrad)
Tellinimera gabbi (Gardner)
Tenea parilis (Conrad)
Aphrodina tippana (Conrad)
Cyprimeria sp.
C. alta Conrad
C. depressa Conrad
Legumen ellipticum Conrad
Caestocorbula crassiplica (Gabb)
C. foulkei (Lea)
C. terramaria (Gardner)
Panopea monmouthensis Gardner
Xylophagella aff. *X. irregularis* (Gabb)
Anatimya sp.
Liopistha protexta (Conrad)

Gastropoda
Euspira rectilabrum (Conrad)
Gyrodes spillmani Gabb
Haustator trilira (Conrad)
Turritella tippana Conrad
Rostellites sp.
Napulus sp.
Pyropsis sp.
Volutoderma sp.
Volutomorpha sp.
Liopeplum canalis (Conrad)
L. cretaceum (Conrad)
Solarium monmouthensis Gardner
Ringicula clarki Gardner

Scaphopoda
Dentalium inornatum Wade

Cephalopoda
Sphenodiscus lenticularis (Owen)
Discoscaphites conradi conradi (Morton)
Eutrephoceras dekayi (Morton)

Crustacea
Protocallianassa mortoni (Pilsbry)